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Yorkshire Geological Society.

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1906—1908.

WITH FIFTY-EIGHT PLATES.

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WILLIAM LOWER CARTER, M.A., F.G.S.,

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VOL. XVI.] [PART I.

PROCEEDINGS
OF THE
YORKSHIRE GEOLOGICAL SOCIETY.

EDITED BY W. LOWER CARTER, M.A., F.G.S., AND
ARTHUR R. DWERRYHOUSE, D.Sc., F.G.S.

1906.

ON THE ORIGIN OF THE BRITISH TRIAS.

BY PROFESSOR T. G. BONNEY, SC.D., LL.D., F.R.S.

In opening this discussion on the Origin of the Trias* I shall restrict myself, as far as possible, to what we can learn about the physical geography and climate of that period from the petrology of the system, leaving one or two points to be more fully described by others. Once for all let me express my obligations for many necessary facts to the Memoirs published by the Geological Survey, especially that on the Triassic and Permian rocks of the Midland Counties, drawn up by Professor Hull in 1869, to suggestive papers on India and Persia by the late Dr. F. Drew and Dr. W. T. Blandford,and to one or two other writers, whom I shall mention in due course.

The name Trias, I need hardly say, was given because the rocks of this system in the typical districts of North Central Europe fall naturally into three groups, which in Germany were called, in ascending order, the Bunter, the Muschelkalk, and the Keuper. In our own country the second is missing, and the third is sometimes uncomformable with the first. But, though I think these two represent very distinct chapters in the physical history of Britain, I would not like to assert that no part of the Muschelkalk had a time equivalent in our islands.

---

* At the York Meeting of the British Association, August 7th, 1906.

The Keuper deposits, speaking in general terms, may be followed continuously from the South Devon coast to the Midlands, whence they extend along both sides of the Pennine Range, on the eastern to beyond the Tees, and on the western to North Lancashire. Here they come to the sea, but may then be traced through the Isle of Man to the neighbourhood of Carlisle on the one hand and the north-east of Ireland on the other. In Scotland also, outlying patches of that age occur on the north-eastern and western coasts. The Bunter, however, as we shall see, is absent from the more southern part of the Midlands, its "beds, in fact, form a wedge, lying diagonally across the central counties, with the apex pointing towards the mouth of the Thames."* It is again found in the south-west, where deposits of that age are exposed on the coasts of Devon and thin out in similar fashion towards the north and east, disappearing in the former direction before reaching the Bristol Channel.

The following facts must be taken into account in any attempt to picture the physiography and climate of the Trias in this part of Europe. Speaking of the Bunter group first, we find that it also very often admits of a triple sub-division, namely, into the Lower Sandstone, the Pebble Beds, and the Upper Sandstone. The first of these deposits, usually unconformable with the Permian beds below, occupies a more restricted area, at any rate in the western Midlands, than the second. Putting aside its representative in northern Lancashire, about the identification of which there has been some dispute, we can trace it from the estuaries of the Mersey and Dee southwards along the borders of Wales and Shropshire. Near Liverpool it is about 400 feet thick; in the neighbourhood of Bridgenorth it attains the unusual amount of about 650 feet. A fault near Bewdley forms its southern limit, but it thins rapidly both in that direction and towards the east, for it does not occur on the northern shore of the Bristol Channel or in the neighbourhood of Manchester and Stockport (having thinned down to 250 feet even at St. Helens), of Leek, the Potteries, Ashbourne, Derby, Wolverhampton, on the southern margin of the Clent and Lickey Hills, and on the western or northern side of the South Staffordshire coalfield. But it forms "a continuous though narrow band extending through Nottingham into Yorkshire." It is usually a soft friable rather homogeneous sandstone, of reddish brown, yellow, and bright red colours, often showing very marked current-bedding, the laminæ of which, in the Bridgenorth district, dip towards the south-east; it is said to be "entirely devoid of pebbles," and beds of well-rolled sand grains are a rather frequent characteristic. These also occur in its Flintshire representative, where, according to Professor Hull, they are sometimes as large as mustard seed.

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* Hull, Permian and Trias (Survey Memoir), p. 61.

The pebble beds occupy a wider area, generally overlapping the Lower Sandstone. They attain in the neighbourhood of Liverpool the great thickness of 1,000 feet, though here sand dominates over pebbles, are about 300 feet thick in the neighbourhood of Trentham and on Cannock Chase, but die out along a line drawn south-east through Leicester. But they appear in Nottinghamshire, where their thickness is said to be also about 300 feet and can be traced northward through Sherwood Forest into Yorkshire. The base sometimes is rather a breccia than a conglomerate. Throughout the mass we find current-bedding and occasional sandy partings, more or less lenticular, the dominant colour being red or reddish-grey.

The Upper Sandstone is generally well developed in South Lancashire and Cheshire, being about 500 feet thick near Wigan, perhaps a little more at Liverpool, from 300 to 250 about Wolverhampton and Birmingham, becoming rather less at Grinshill in Salop, though it may be traced southward as far as the Abberley Hills. In Cheshire this group also thins towards the east; it is not found along the borders of the Warwickshire and Leicestershire coalfields, and is commonly not represented "along the band of country which stretches in a northerly direction from the valley of the Trent at Nottingham to the

Humber." It varies in colour from red to yellow, exhibits current-bedding, contains "millet seed" beds, and much resembles the Lower Sandstone, but is rather finer grained.

Thus the Bunter as a whole disappears south of a line running through the southern parts of Leicestershire, Staffordshire, and Warwickshire, and is not again found north of the Bristol Channel.* In the southern area its chief development is between the mouths of the Exe and the Axe, where the Pebble Bed reaches a thickness of about 100 feet, the Lower Sandstone is apparently wanting, and the Upper is represented by a soft sandstone measuring about 450 feet. Some differences of opinion exist about its exact limits, but into these we need not enter. Suffice it to say that the dimensions of the southern Bunter are much inferior to those of the northern, for it thins rather rapidly towards the north and the east, dying out in the course of some 30 miles from the coast.

The Keuper, as a whole, exhibits no such interruption, and its deposits differ considerably in their mineral character. It also (I exclude the Rhætic) often admits of a triple sub-division—the Lower Sandstone, the Waterstones, and the Red Marl. The first, more often grey than red in colour, is occasionally pebbly and has a breccia at its base, the third is a red clay, banded with pale greyish-green, sometimes containing masses of rock salt and of gypsum, and with occasional lenticular intercalations of sand or breccia, the latter having been formed near shore lines, while the second deposit, the Waterstones, is obviously a transitional one, rather thin beds of sandstone, commonly grey in colour, alternating with layers of Red Marl. East of the Pennines the Keuper sandstone is sometimes wanting, but it is about 120 feet thick near Nottingham, and is well developed around Derby. In South Lancashire, Cheshire, Staffordshire, and Shropshire it is often some 200 feet thick, probably attaining, according to Professor Hull, its maximum thickness, from 400 to 450 feet, in the neighbourhood of Stourbridge. Its basement often consists of breccia, like that of the Bunter, angular fragments of more or less local rocks being mixed with pebbles, characteristic of the latter formation; similar pebbles, frequently of quartz, but sometimes of clay, and generally rather small, occurring occasionally in the sandstone itself.

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* I have not taken account of the St. Bees sandstone, now generally regarded as Bunter, because so far as I am aware we have no means of determining its exact position in that group. Mr. H. B. Woodward says it varies in thickness from 500 to 2,000 feet.

The Waterstones consist generally of alternating layers, usually not thick, of similar greyish sandstone and red marl, like that in the uppermost division. Its maximum thickness, so far as I can ascertain, is about 300 feet, but it seldom exceeds half that amount and is often thinner, so that, as it is obviously a transitional formation, we may pass on to the Red Marl. This overlaps even the Lower Keuper sandstones, and maintains its lithological characteristics, as already mentioned, from the north-east of Ireland on the one hand and Yorkshire on the other to the extreme south on the Devon coast. Probably it extends beneath the sea to France, for the Keuper Marl in Normandy, where I saw it, closely resembled that of our own country. This formation apparently attains its greatest thickness in Cheshire, where Professor Hull makes it about 3,000 feet; in the central parts of Staffordshire it may be some 1,500 feet, but in the neighbourhood of Coventry and Warwick this is reduced, according to Mr. Howell, to 600 feet. That is about its measurement in Gloucestershire and Nottinghamshire; apparently it becomes thinner in the neighbourhood of the Bristol Channel, but thickens again towards the south, attaining from 1,000 to 1,350 feet on the shores of the English Channel. Where it abuts on older rocks, intercalated breccias are not unfrequent, obviously formed near shores with a rising strand line; of these the so-called Dolomitic Conglomerate in the Mendip region is a conspicuous example. The Keuper Marl, indeed the Trias as a whole, obviously thins out in the neighbourhood of Northampton, for its total thickness in a boring near that town was just under 60 feet, while it was not found beneath the London and North Western railway station, or under Kingsthorpe, Kettering, or Orton. It has not been struck in any of the borings in the eastern counties from Suffolk to Kent. In saying this I do not forget the red rocks found beneath Kentish Town, Crossness, Richmond, and Streatham, but I am convinced that these are really Palæozoic.

I now pass on to some lithological details in these deposits and take first the most conspicuous, the pebbles in the Bunter conglomerate of the northern and southern areas, in both of which no small variety of rocks is represented. The majority are at least sub-rotund. On Cannock Chase, where I have chiefly studied them (though I have sampled other places from Birmingham to Liverpool), the pebbles vary much in size. Those from a horsebean to about two inches in diameter are common; very many are between three and four inches; a few run still larger, up to six inches, and occasionally even exceed that. Several kinds of rocks are represented, but in regard to this, as I have already discussed the petrography of the pebbles,* I shall restrict myself to a brief summary. Vein-quartz and quartzite are the most abundant; the former are usually white, but include, though rarely, black tourmaline; some are brecciated. Quartzites are numerous and have their grains in a large number of cases very perfectly cemented. They vary in colour from almost white to a dark tint; some are reddish, and the characteristic liver-coloured variety is not rare; sometimes they are speckled with red felspar and thus graduate into a rock exactly resembling the noted Torridon sandstone. Pebbly quartzites also occur, and others shade off into hard sandstones, some of which are fossiliferous. Various mudstones, to use an inclusive term, are also present. Pebbles varying from dark green to almost black in colour are not uncommon. These are generally fine grained quartzites, darkened by interstitial chlorite, tourmaline, or iron oxide, some of the most compact proving to be porcellanites or cherts, the latter occasionally containing radiolaria. Chert also occurs with the well-known casts of crinoid stems, and limestone with characteristic Lower Carboniferous fossils. Neither are common, though the latter is perhaps a little more so towards the base of the pebble beds, and has recently been found rather more abundantly in one of the pits on the Satnall Hills, between Rugeley and Stafford.

The fossils, however, which have attracted most notice occur in the quartzites. In that large compact group, mentioned above, we find only a very few annelid tubes, often rather large;

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* Quart. Jour. Geol. Soc., lvi. (1900), p. 287.

the majority form casts in a pale greyish or reddish sandstone, usually so hard as to be almost a quartzite. The pebbles are generally, but not always, about as well rolled as the others, and range with them in size. After what has been written, I need only say that at least the majority belong to the Upper Llandovery. A few other Silurian fossils have been found in more argillaceous rocks, and two or three bits of silicified wood, perhaps Permian.

Passing to the crystalline rocks, we find that granites, gneisses, and mica-schists occur but rarely and are usually much decomposed. Felstones, however, to use a convenient field term, are rather common. After the descriptions which I have given of these, it will be enough to repeat that they have evidently travelled far, have very little resemblance to the so-called Uriconian felstones of the Midlands, or to any known to me in the Lake District, and none to those in North Wales. Many of them, however, correspond closely with the felstones so abundant in the Highlands and other parts of Scotland, though they often contain tourmaline, which is a rare mineral in that country.

I pass on to the contents of the pebble bed in the southern Bunter. I described those at Budleigh Salterton in 1895, and may refer for particulars to the paper published in the *Geological Magazine*.*

Most of the rocks mentioned above also occur there, but not in the same proportion. The fossiliferous hard grits or quartzites which, though more numerous, are not abundant, attracted the attention of palæontologists many years ago. They were found to represent Lower Devonian, Bala, and Arenig grits (the last occurring very sparingly), and often have a closer lithological resemblance to corresponding deposits in Normandy than to those in Britain. The non-fossiliferous grits or quartzites are perhaps rather more frequently speckled with minute grains of felspar than in the Midlands, but the most marked difference is one of form. "Pebbles which are nearly prolate spheroids occur in both deposits, but that is the common shape in Staffordshire, while those in Devonshire are usually oblate." Corresponding with this is the comparative rarity of the almost vitreous quartzites of the Midlands, those common at Budleigh Salterton bearing a general resemblance to quartzites such as I have seen in the Gorran Haven district. Tourmaline-bearing grits are, I think, more common, often in rather larger and more rectangular pieces than in Staffordshire, but the felstones are less abundant; the very characteristic rocks of the Lizard peninsula, with the granites of Devon and Cornwall and the Devonian limestones, so far as I could see, did not occur.

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* Volume for 1895, p. 75.

Such pebbles as I have examined from the Keuper, when not of local origin, as in the breccias, correspond with those in the Bunter, being usually quartzites and vein-quartz, and are seldom large. They prove, however, that the source from which the latter may have been derived continued, though more sparsely and intermittently, to supply materials until the setting in of the Red Marl.

We must not, however, forget the smaller clastic materials. The Bunter sandstones of the Midlands are largely composed of quartz, stained externally with ferric oxide. In the upper and lower divisions well-rounded grains, as I have said, are abundant at certain horizons, but they are less common, so far as I have seen, in the matrix of the pebble bed. Grains of iron oxide may be observed, and no doubt rarer minerals will be found if sought for. Mr. H. H. Thomas has shown by his admirable investigation of the sands in the Devonshire Pebble Bed how rich a harvest awaits the investigator.* Among its rarer minerals he found garnet, anatase, rutile, zircon, apatite, brookite, sillimanite, staurolite, cyanite, and titanite, with micas and felspars, besides fluorspar, cassiterite, and tourmaline. These suggest a derivation from rocks, the representatives of which still occur in southern Cornwall and may now be concealed beneath the waters of the English Channel.† It is noteworthy that nearly all those in the first-named group, together with tourmaline, have been detected by Mr. A. B. Dick and others in the Lower Bagshot sands (at Hampstead), the materials of which are generally supposed to have travelled from the south-west.

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* Quart. Jour. Geol. Soc., lviii. (1902), p. 620.

† See W. A. E. Ussher, Q.J.G.S., xxxv. (1879), p. 245.

What inductions then, as to the physical geography and climate of the British Trias, follow from these facts of distribution and petrographic character? In the first place, as I have already said, the history of the Bunter is one thing, that of the Keuper another. Assuming that the Pennine Range existed throughout the Trias, I proceed to inquire whether the materials of the Mid-England Bunter came from a northern or a southern direction. The former inference is supported by the gradual thinning out of the three members as they are traced from South Lancashire towards a line which may be drawn from rather north of Worcester to Leicester, and on the whole by the petrography of their materials. For the abundant sand we may look to more than one source in Scotland, augmented by the grits of Carboniferous age in the Pennines. No other source of supply is visible; the Old Red Sandstone of South Wales mostly lies too far to the south-west; only slight hints have been found of any similar rock beneath Mesozoic deposits to the south-east of the above-named line; the vein-quartz pebbles help us little, for that rock occurs in so many places; the more characteristic quartzites do not closely resemble any exposed in Wales, Shropshire, or Warwickshire, but are exactly like those which occupy large areas in North-western Scotland and are abundant to the south of it in the Old Red conglomerates. The same may be said of the quartz-felspar grits; they are exactly like the Torredonian which underlies that quartzite and do not so closely resemble that of the Longmynd, which in Triassic times cannot have occupied a much larger area than it does now. The felstones also can only be identified in Scotland, where many of them occur abundantly both *in situ* and as pebbles in the Old Red Sandstone conglomerates.

But this hypothesis of a northern derivation of these Bunter pebbles involves two difficulties. One is the not unfrequent occurrence of tourmaline in felstones, quartzites, and vein-quartz. This mineral is abundant in the south-west of England, from which general direction I have no doubt the South Devon Pebble Bed derived its materials, but it is very rare in the north. It has, however, been found by Mr. C. T. Clough in vein-stones and in pebbles of an Old Red Sandstone conglomerate on the

English side of the Cheviots,* as well as in Scotland, and is not rare as a vein product and in a schistose slate in the Isle of Man, so it may have been more abundant in the rocks which disappeared in forming these Midland pebbles. The other difficulty is also serious, that the pebbles are more abundant in Staffordshire and its immediate neighbourhood than they are in the district round Liverpool. They are, however, more frequent there and of greater size than is sometimes supposed, but they are more largely mixed with sand, for the pebble bed as a whole is, as already stated, fully three times as thick in the latter as it is in the former district. Near Liverpool we seem, as I have more than once observed, to be out of the main course of pebble deposit and in that of sand deposit, so that the difficulties are to some extent antagonistic. I think they may be reconciled by supposing that in what is now Lancashire the main current of the river happened to occupy a narrower channel than it did in Staffordshire.

Here, however, I have anticipated a little in speaking of a river, for some have considered the Bunter to be a marine deposit. But in that hypothesis one difficulty appears to me insuperable. Pebble beds formed by the sea are always limited in one of their three dimensions; if thick they are narrow, if widespread they are shallow. The Bunter Pebble Bed in Staffordshire is broad, and long, and thick. To this I may add that it presents a remarkable resemblance to the pebble beds formed by rivers issuing from mountain regions. For some 20 years I have paid considerable attention to the Alpine gravels. The Nagelfluhe—a Miocene deposit—resembles in many respects the Bunter gravels, and the Molasse, with its occasional seams of pebbles, is not unlike the Keuper sandstone. The Pleistocene or very late Pliocene *löcherige Nagelfluhe* or *Deckenschotter* closely resembles the Bunter in mode of deposit and distribution, but is a little coarser and more "tumultuous" in aspect, while the older Alpine river gravels, except that they are restricted to narrower channels, present a still closer resemblance.

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* Geol. Survey Memoirs, The Cheviot Hills (English Side), C. T. Clough (1888), p. 16.

So we can hardly be wrong in claiming the Bunter as a fluviatile deposit. But some of those, who admit this, deny, for the reasons indicated above, that the river or rivers which brought the materials to the Midlands came from the north. The pebbles, as I have more than once pointed out, must have had a long journey, and could only have been transported by a strong stream—not less than that of the Rhône between Martigny and the Lake of Geneva. Volume and velocity demand that such a stream should have been fed by a mountain region.* Were such a region buried under the post-Triassic Mesozoic deposits in the south-eastern half of England, it must have disappeared with remarkable celerity. Hills there may have been in this direction, but the Lickey and Clent ridges, and the rugged Charnwood upland, besides being composed, with rather rare exceptions, of rocks differing in character, cannot, even in that age, have been much more elevated than at the present day, But, it has been urged, the river, after depositing the Budleigh Salterton pebbles, made its way to the Midlands by some buried channel. The grave keeps its secrets, but, as I have already said, the dominant quartzite pebbles at the former locality differ widely from those of the Midlands, and the idea that the latter have been sorted from the former, because their shape made them travel more easily, seems to me rather like expecting the riddlings of a peck to fill a bushel. In considering this question we must not forget, as some authorities appear to do, the great volume of material which must be broken up and transported to make not only the Bunter as a whole, but even its pebbles. The latter alone, as I pointed out in an address to this Section at Birmingham in 1886, is probably equivalent in bulk to a hill range twenty miles long, two miles wide and a thousand feet high. Neither Wales nor the Lake District could supply the right rocks, even if Dr. Marr would allow the latter to be visible at this epoch. In the north alone do we find almost all the rocks needful, and from this quarter volumes of material —sand and mud—as Professor Hull showed in two very suggestive papers more than 40 years ago,† must have travelled southwards in the later Palæozoic and earlier Mesozoic periods, during which also, and for even longer, we have evidence of a similar transference from a somewhat similar region lying to the south-west of England. Of this great mountain region, as I have often pointed out, Scandinavia, the Highlands, North-west Ireland, Cornwall, and Brittany may be fragments, the present 100 fathom line possibly giving some clue to the position of its watershed.

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* See "Rounding of Alpine Pebbles," Geol. Mag., 1888, p. 54.

† Quart. Jour. Geol. Soc., xvi. (1860), p. 63, and xviii. (1862), p. 127.

If the Bunter group were deposited by a river flowing northward we can only dispose of its waters by supposing them to have been absorbed, for an outlet in that direction would require some startling and yet temporary changes in physical geography. The former fate would not, I think, be in itself improbable. The upper and lower Bunter, with their wind-worn sands and widespread fragmental deposits, are very suggestive of a desert lowland, and in such regions absorption is always possible; an ending which must not be forgotten even supposing the river to have flowed southward or south-eastward, for we find it rather difficult to ascertain its ultimate course in that direction. It may, however, have passed through a restricted channel on one or the other side of the Charnwood Hills. A southward drift of material, generally no doubt argillaceous, during Jurassic times and along a channel opening towards North-western France is more than suggested by the results of borings in South-eastern England, especially by that at Netherfield near Battle.

As I have been forced to dwell at considerable length on the Bunter sub-division, and there is a more general agreement about the Keuper, I shall pass rather briefly over that. The lower Keuper sandstones may well have been deposited under somewhat similar conditions to the Bunter, but which corresponded more closely with those of the Swiss Molasse. Fossils, as Mr. Lomas will tell you—Reptilian or Amphibian, with fish, annelids, a few mollusca, very imperfectly preserved, and some plants—are not altogether wanting in the Keuper Sandstone or the Waterstones,* and both, but especially the latter, with their footprints, ripple marks, sun cracks, and rain prints, are highly suggestive of incipient salt-lake conditions, where the level of the water is liable to rhythmic oscillation. That the Red Marl was an inland sea deposit is, I think, now generally admitted, and confirmation is found, if that were needed, by Professor Watts' remarkable discovery of sand-worn rock surfaces at Charnwood and Mr. T. O. Bosworth's finding of "millet seed" grains, both in the intercalated sandstone and even, as he has recently informed me, in the marl itself in more than one part of Leicestershire. In regard to the former, I may say that I now think it probable that a slight planing off of the surface ridges of rock at Charnwood and near Narborough, which formerly I thought might be due to grounding ice, may really have been the effect of sand-drift. Mr. Strahan also has called attention to the fact that the paucity of organic remains in the Keuper is suggestive of desert conditions,* and the evidence collected in the Reports published by the Association after the last three meetings points in the same direction. But I think that the Red Marl as a whole is an aqueous rather than an aerial deposit, or in other words that it differs from the rest of the great Mesozoic clays only in being formed in an inland sea instead of in one communicating with the ocean. The frequent shore breccias, especially in the south of England, as I stated in my paper† on the relation of such deposits to the physical geography of their age, suggest a climate rather liable to extremes and not improbably arid, something like that of Persia, or perhaps even Eastern Turkestan at the present day, and such a climate may very well have continued from the beginning of the Permian, with its important breccias of Rothliegende age, to the end of the Keuper, when the sea again invaded the British lowlands, over which it ebbed and flowed till almost Mid-tertiary ages. How far this episode of a marked Continental climate was due to a combination of Caledonian and Armorican foldings is an inquiry into which, though full of interest, time forbids me to enter. Enough to say that, if a mountain chain, capable of feeding rivers, comparable with those which now issue from the Alps, were situated anywhere near the present 100 fathom line, and precipitated the vapours coming from an ocean yet farther west, the climate in the lowlands, of which I have been speaking, might very well be much more arid and extreme than it is at the present day.*

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* They are not quite absent from the Red Marl.

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* Geol. Survey Memoirs, South Wales Coal-field (Bridgend).

† Quart. Journ. Geol. Soc., lviii. (1902), p. 185.

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* See F. Drew, Quart. Journ. Geol. Sci., xxix. (1873), especially pages 442–43; also W. T. Blandford, id., p. 493, etc.

ON THE ORIGIN OF THE TRIAS.

BY J. LOMAS, A.R.C.S., F.G.S.

It is becoming more generally recognised day by day that the Triassic Rocks of Great Britain can best be explained by assuming that desert conditions existed during their formation.

In order to test this it may be well to examine briefly the conditions now existing in deserts and the activities now at work in those regions. While desiccation is one of the controlling factors in the deserts of to-day, we find none which are absolutely free from water. Deserts may exist with a comparatively large rainfall, provided it falls in a limited time, is quickly shed, and not stored up by glaciers, soils, or lakes.

Thus streams which exist in the rainy season soon become dry, and for the rest of the year they are not functional. In South Africa we constantly come across deep channels excavated by streams, their beds covered with large stones which could only be carried by torrents. During the dry season sands blow into the hollows and completely obliterate all traces of the stream courses. In the next rainy season the streams may or may not find their old channels, and thus by constant excavation and in-filling we get deposits covering the country, consisting mainly of blown sands with patches of gravel marking the sites of former streams.

Wind acting on deposits like those just described sweeps away the sand to longer or shorter distances to form heaps or dunes. The finer particles will come to rest at one place and the coarser at another. In this way we get a more or less perfect sifting into sizes. I have examined many samples of sand from the Sahara and other deserts, and find this sifting to be one of the chief characteristics of blown sand. In one place I was fortunate enough to get specimens of beds in vertical order, and found that while the grains were uniform in size for the same horizon, they differed very much from bed to bed. The stones too heavy to be moved by wind tend to drop down to a lower and lower level, and form a stratum composed wholly of large stones, with little or no sand intermixed. This explains one of the features which strikes an observer in visiting a desert region, where he finds great stretches of pebbles of all sizes strewing the ground, while in the distance he may see the dunes of sand composed of materials which were formerly mixed with the pebbles.

When deposits such as these are worked up and re-worked up by wind action year after year, there is a tendency towards a concentration of particles of one size at one place. We shall see that in other respects *concentration* is the dominant feature of desert areas.

Another way in which the desert shows itself as an area of concentration is in the materials brought down by rivers in solution. Evaporation may take place during transit, and the sand through which the streams flow may be coated with salts. In flashes or shallow pools held up by the irregular disposition of sand dunes, water may remain for a longer period, even through the dry seasons, and then it becomes strongly charged with salts, which may crystallise out as common salt, gypsum, iron pan, carbonate of lime, and other substances. Mud and drifted vegetation carried down by the streams may be deposited at the bottom of these flashes, forming a puddle, and preventing the escape of water below. On drying, we have left a mud, strongly charged with salts, which cracks on desiccation, and this may take the imprints of animals which come to drink and impressions made by rain drops and runlets of water. Sand blowing into these shallow pools will bury the lower deposits, and preserve there the markings impressed on them. In the deserts of South Africa we often find white nodules in the sand consisting of carbonate of lime cementing grains of sand. These vary in size from a marble to gigantic masses. Sometimes they form continuous layers, and I have seen them 10, 20, or 30 feet thick. The carbonate of lime is precipitated out of solution by loss of carbonic acid, and after deposition it is not easily removed from the sand grains it coats. Hence carbonate of lime concentrates on land rather than in pools.

A third way in which concentration is seen in deserts is shown by the manner in which organisms tend to cluster round places where water is more or less permanent. We should naturally expect to find plant life and aquatic animals more abundant in those places. A salt pan near Riverton, in South Africa, I found to be swarming with the little Crustacean Estheria (the most common and most widely distributed fossil in our Trias), and larger animals coming there to drink leave their footprints and other remains in the mud.

Now to apply these principles to our Trias. It is generally accepted that the material forming out Triassic rocks was originally river borne. I shall not stop now to discuss the origin or courses of these rivers, but, given the deposits and a desert or semi-desert condition of climate, we can see how wind would in places concentrate the coarser fragments, forming deposits like the Pebble Beds of the Midlands. Some localities may have escaped the sifting, and the Pebble Beds of Lancashire and Cheshire, in part, may represent these. In the latter counties we find very thick masses of sand, false bedded, in a way which suggests dunes rather than river deposits, and lenticular patches of pebbles interspersed at all horizons and very inconstant in extent. I have not made careful calculations, but it strikes me that if the pebbles in the Lancashire and Cheshire areas were concentrated as in the Midlands, they would make up a deposit quite as thick and of a similar nature. It has been asserted that the pebbles of the Midlands are larger in size than those further north. I know places in Lancashire and Cheshire where they range up to 6 in. or 8 in. in diameter, and my experience in Cannock Chase and other places in the Midlands is that assemblages of a larger size than this require looking for. Large pebbles are exceptional and do not characterise the beds as a whole.

On this hypothesis, the Pebble Beds of the Midlands and further North may differ only in one having been subject to the concentrating influence of wind and the other having to a large extent preserved its original character, and being abnormally thickened by the importation of fine material from the Midlands. We should naturally expect that the stones over which sand has drifted in the course of concentration would be etched or planed to form dreikanter. These are found in the Pebble Beds but are not common. Neither are they in existing deserts.

The striking feature of the Upper Bunter is the way in which the various horizons are characterised by even sized grains. In some beds it looks as if the material had been put through a sieve or a series of sieves of different meshes. A bed may preserve an even grain for a few inches only, and be succeeded by one of different size, but uniform for the same horizon. In no deposit laid down under water could this feature be so perfectly developed.

Coming now to the Keuper, we find the basement beds are characterised by the occurrence of pebbles and rolled clay nodules, and a thin band of marl, at least in the north, usually intervenes between the Keuper and Bunter. In places, as at Alton in Staffordshire, concentration of pebbles has taken place and wind etched pebbles are not uncommon.

The Lower Keuper, I believe, marks a pluvial phase following desert conditions. Above this the Keuper sandstone is characterised by an increasing frequency of marl bands. These are never of very great extent, and are always half lenses with the convex surface downwards. They may represent the flashes and shallow pools of the desert or semi-desert region, and it is on their shores we find the footprints of reptiles, Estheria, and other organisms, and pseudomorphs of rock salt. The last phase of the Keuper is represented by the Keuper Marls. It is a misnomer to call them Marls, as clay enters but little into their composition, except in a few localities. The mass of the rock is composed of exceedingly fine, splintery, angular grains of quartz which seldom exceed $\frac{1}{500}$ to $\frac{1}{1000}$ in. diameter. Large pools or lakes existed at this time with the concomitant beds of salt, gypsum, &c., and footprints, Estheria, and drifted plant remains are common. The Keuper Marls may represent the material accumulated by the feeblest currents of wind, the fragments blown furthest, and as such may be compared with the Loess of Eastern Europe.

Taken as a whole, we may regard the Trias formation as made up of a series of lenticular beds, irregular in their disposition and piled up mostly by wind action, but before they can be properly read we must know a great deal more about deserts, not only what they are, but what they do.

DISCUSSION ON THE ORIGIN OF THE TRIAS.*

Mr. T. H. Holland referred to certain phenomena in the Rajputana desert that supported Mr. Lomas's views with regard to the processes of concentration in arid regions. He referred to the separation of the finer angular sands (which were carried bodily in the wind and became deposited in the North Eastern area, where the force of the wind was diminished) from the rounded grains formed by the rolling of grains too heavy to be carried by the wind. With the finer material in the neighbourhood of Bitraner, Mr. La Touche has described the occurrence of undamaged tests of foraminifera, which must have been carried in the wind some 500 miles from the Kathiawar Coast.

Mr. Holland also described the occurrence of the silt beds filling in hollows in the Archæan surface, having a general plano-convex lens shape, and being charged with salt, beds of gypsum, and concretionary nodules of carbonate of lime such as Mr. Lomas had described in connection with the Trias. He was not prepared to admit that the features of the British Trias were due only to wind action, but in the main, they were due to the conditions prevailing in desert regions, where, during monsoon seasons, there may be a heavy rainfall for a limited period, with rivers in flood, and all the usual phenomena of river action.

Prof. J. W. Gregory dealt with the conditions found in the Australian desert, and said that the deposits now forming these reminded him of the Trias of Cheshire.

Prof. Grenville A. J. Cole said that in dealing with the British Trias we must never forget the great sea eastward, and the likelihood of the establishment of a monsoon system upon its margin. The geographical conditions seemed well suited for this, and an intense rainy season lasting, say, three months, might easily, year after year, sweep down and redistribute materials which remained dry for the other nine months. Sheets of pebbles without well defined water channels are compatible in such cases with general conditions of desiccation.

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* At the York Meeting of the British Association, following the papers by Professor Bonney and Mr. Lomas.

Mr. R. D. Oldham asked "What is a desert?" He referred to sand deserts, rock deserts, and mud deserts, the last having a slightly rolling uneven surface in which rains accumulate. He considers that the only agency capable of forming pure sands of large extent—hundreds of miles—and very thick, is wind.

Mr. Clement Reid discussed the peculiar plant adaptations found in deserts. They are generally provided with stiff stems and fronds like Cycads. As far as we know the Triassic flora, the same habit occurs.

Dr. J. J. H. Teall pointed out that 25 years ago, Sir A. Ramsay, speaking at a meeting of the British Association at York, suggested that the British Trias was of desert origin.

ROMAN REMAINS AT FILEY.

BY THE REV. E. MAULE COLE, M.A., F.G.S.

A.—*Previous Notices.*

I.—Original paper by W. S. Cortis, M.D., published in the Scarborough Philosophical and Archæological Society's Reports, XXVI. (1858), p. 18 sq.

Full title—" Remarks on the Discovery of Roman and British Remains at Filey, Yorkshire, in October, 1857, with some observations on the Position of Portus Felix and Prætorium." Gives all particulars, with plan of ruins as excavated, drawing of squared stones, now in Filey Gardens, of remains of pottery and inscription on slab of shale,

Cæsar se
Quam spe

II.—Paper by John Phillips, in Yorkshire Philosophical Society's Proceedings, 1858. Very brief ; does not mention the inscription.

III.—Whellan's Yorkshire, II. (Beverley, 1859), from Cortis.

IV.—Wright, Intellectual Observer, VIII. (1866), p. 234. Read at Durham Archæological Association Congress. He saw the inscription.

V.—Hübner, Ephemesis Epigraphica, iii., No. 125, p. 143.

VI.—Watkin, Archæological Journal, 31 (1874), p. 349. The two latter follow Wright.

VII.—Cole, Paper on Roman Roads, E.R. East Riding Antiquarian Society's Transactions, Vol. VII. (1899), p. 42, 43.

B.—*Brief History of Find.*

After some heavy rains in the autumn of 1857 a landslip took place on the N. side of the boulder-clay cliffs of Carr Naze, which attracted the attention of a painter at Filey, named

Wilson. From what he saw the circumstance was communicated to the then owner of the land, the Rev. R. Brooke, of Gateforth, near Selby, who decided to make an excavation in the ground above, the result of which was to discover some outer stone walls of an enclosure, 22 feet wide by 50 feet in length. Within this was a stone-wall building, 15 feet by 10 feet internally, with an entrance from the west. Outside this, a few feet to the west, five square stones were discovered, each about 20 inches in height, and measuring about 2½ feet square at the base. They were placed in the form of a parallelogram (17 feet by 14 feet), four at the corners and one in the centre. Each contains a mortise at the top, 7 inches square and 3 inches deep, intended doubtless for a wooden pillar or shaft to support a roof.

In addition to these remains of buildings, some 40 late Roman coins were found, quantities of animal bones, and pottery of Roman and Romano-British Age.

C.—*Theory Built on the Find by Dr. Cortis.*

That this is the site of an important Roman station, no less a one indeed than Prætorium, to which a military road ran from the borders of Scotland, as described in the 1st iter of Antonine.

D.—*Derivations of Words to Bolster up the Theory.*

(*a*)—The place-name Filey is supposed to be derived from Felix, because Richard of Cirencester, an imaginary character and a myth, speaks of Portus Felix as equivalent to the "eulimenos kolpos" = "well-havened bay" of Ptolemy, and Filey Bay is considered, though erroneously, to answer to the appellation.

(*b*)—The "Carr" in Carr Naze is assumed to be the same as Caer (castra, a camp), as in Caerleon and Carlisle, though in place-names it is an anomaly to find two different languages combined.

(*c*)—The word "Brigg" is suggested to be a shortened form of Brigantium, and to represent the noble promontory which formed the eastern limits of the Brigantes.

(*d*)—The word "Spittal" attached to some masonry jutting out from the S. side of the Brigg is playfully derived from hospitium, and the little landing-stage dubbed Roman work in consequence.

Now let it be said at once, that apart from theory and false derivations, the find itself is unique, and therefore of much importance. There is no other known instance of a Roman building on the East Coast of Yorkshire. But why exaggerate? It was not a station, not even a villa. There was no tesselated pavement, no hypocaust. It was simply a block-house, such as one may see on the Roman wall. Mr. F. Haverfield, writing to me in 1890, says of it, "The place was perhaps a sort of hall for accommodating a small garrison."

Considering the number of roads radiating from Eboracum (York), the seat of Government in Britain in Roman times, to the coast, it is somewhat remarkable that no trace of a building, other than this, has ever been found. The Romans, during their occupancy of Yorkshire for several centuries, must, one would imagine, often have had resort to the coast, either for pleasure or profit, as people do now, and not only have had houses to go to, but also landing places for troops or commerce, and guard-houses to protect them against incursions of freebooters, with probably a coast-road to connect the various stations. How is it then that only one single outpost has been discovered, namely, that at Carr Naze?

The answer is not far to seek. The denudation of the boulder-clay cliffs throughout Holderness, and in all the bays northwards, charged with the same material, has been so rapid, amounting on an average to two yards or more a year, that a strip of nearly two miles of land has been removed from the coast line since Roman times. All has disappeared beneath the sea, even Prætorium itself, if it ever existed on the sea coast.

The crux is to find Prætorium. The problem has exercised the minds of many antiquaries and inquirers after truth for many generations. Like the site of the battle of Brunanburg it is still unsolved, and will probably remain so. If it could be, we should be able to determine the road which led to it, and the site of Delgovitia, which at present is an unknown quantity. All that we know from the 1st iter of Antonine is that a road from the borders of Scotland passed southwards through Catterick and Aldborough to York, and was then continued to Derventio (vii., m.p.m.), Delgovitia (xiii., m.p.m.), and Prætorium (xxii., m.p.m.). The letters m.p.m. mean "millia plus minus," as Dr. Raven has proved to me. The distances given are therefore only approximate.

By universal consensus Derventio is identified with the modern Stamford Bridge on the Derwent, but whether, after that, the road passed (*a*) south to Brough on the Humber, across Barnby Moor, or (*b*) east to Bridlington through Fimber, or (*c*) north to Malton by Gally Gap and Mook Street, and so (1) by Settrington High Street and the Dale towns to Bridlington, or (2) at the foot of the Wolds, by Sherburn and Flotmanby Street to Filey, it is impossible to say. *Quot homines tot sententiæ.*

My own opinion is, after years of thought and study, and with a perfect knowledge of the ground, that the road, a military way, I presume, after passing so great a distance in a southerly direction, would be unlikely to diverge to the north or east, but would continue in its southerly course across the Humber to the important colony of Lincoln, where it would form a junction with the Fosse way from Devon, and the Ermine Street from Colchester.

As an alternative I infinitely prefer the road by Garrowby Street and Fimber to Bridlington Bay, the safest roadstead for ships of the period and the nearest point from York.

I come now to the derivations :—

Filey from Felix is manifestly "absurd" (Haverfield).

Carr Naze. Naze or Næs is pure Norse, and one of the most common place-names in Norway. Carr may be a personal name. It occurs in the Laudná ma-bók of Iceland, and is widely spread in the Danish districts of Yorkshire, or, more probably, it may be taken from the numerous "carrs" which are found in the Vale of Pickering to the west of Filey. Icelandic, kjarr= brushwood.

Brigg. Another purely Norse word. Icelandic, brygga= a pier, landing stage. It is so used to-day in the harbour of Bergen.

Spittal. I cannot account for this word as applied to the projecting masonry, only uncovered at very low tide, unless it is a form of spit=a spear or lance, Dan., spyd, meaning here something which sticks out.

Anyhow the names Carr Naze and the Brigg point to Norse occupancy, and not to Roman.

Finally as to the inscription, "Cæsar se quam spe," Mr. Haverfield remarks, "The genuineness of the inscription may be doubted. I am inclined to think it forged. Certainly nothing can be guessed as to the sense of it from the letters now upon it."

STRIATED ROCK SURFACE ON HARDEN MOOR, NEAR BINGLEY.

BY E. E. GREGORY.

(*Read March 1st,* 1906.)

During an excursion from Bingley to Harden Moor, on Whit-Tuesday afternoon (June 13th, 1905), an interesting discovery was made. Some friends and myself had been searching for a supposed Roman road, when, quite unexpectedly, an exposed surface of Rough Rock bearing glacial striations was found.

The striated surface is exposed for a number of yards on the rocks known as the "Lower Crag," and just above the "Crag Cottages." It is situated about 650 yards in a north-westerly direction from the centre of Harden village, and just below the 700 feet contour line. The general direction of the striæ is from a point about 65° W.N.W., extending towards E.S.E. It is interesting to note that, during its progress, the ice was deflected towards the west at this point; this is proved by the fact that, in another position about 30 yards to the south-east, the striæ have a direction of only 20° west of north, bearing to the S.S.E. (True north.)

Note.—The exposure was again visited on June 5th, 1906, when further evidence was found on this same crag The more recent record is about 40 yards north-west of the first-mentioned exposure, while the direction of the striæ here is 50° W.N.W., pointing to E.S.E.

E. E. G.

THE STRUCTURE OF SOME CRAVEN LIMESTONES.

BY ALBERT WILMORE, F.C.S., F.G.S.

(*Read March* 1*st*, 1906.)

PART I.

The Limestone Rocks which this paper deals with occur in the anticlinal system of the Craven Lowland country. The district is somewhat triangular, having Clitheroe, Skipton, and Hellifield at the angular points.

This interesting district has a physical geography very different from the district north of the Craven Fault systems which bound it on the N.E. side, and which may be termed the Craven Highlands. It nowhere rises to more than about 700 feet above sea level, and is singularly uniform in its general aspect. Low, well-rounded hills, with contour lines making series of concentric circles, and with the valleys between them more or less filled with confused alluvial and glacial drift, occupy almost the whole district.

In the south-eastern part of the district there is a simple dissected anticlinal—the well-known Clitheroe anticlinal—with the dip and the strike on the whole very uniform on the S.E. side facing the Pendle range of grit hills, but with numerous faults and rolls on the N.W. side. Quite sharply contorted beds with faults occur at Sawley Grange, Foxley Bank, Grindleton, and West Bradford Brook (see Plate I., Fig. 1). On the south-eastern side of the anticlinal massif there are four or five prominent knoll-like masses, three of them forming prominent peninsulas, one a well-marked cape, and one an island in the low ground of Pendleside shales (shales with limestone of the Survey), much of which is covered with glacial drift. These knolls—fine examples of the Reef-knolls of Mr. Tiddeman—have been the subject of much discussion, and it is proposed to refer to them in a later part of this paper.

The simple anticlinal of Clitheroe and Chatburn becomes a much more complex system when traced east towards Skipton and north-east towards Hellifield. At Gisburn there is a well-marked simple anticlinal—which may be called the northern lobe of the system. Exposures on the northern side of this anticlinal are very numerous and the dips are tolerably uniform.

At West Marton and on to Swinden Moor there is a fold crossing this system—a synclinal fold or a fault must be hidden under the drift at Horton—and this fold has its axis parallel to the main Pennine axis, that is, nearly at right angles to the general strike of the beds elsewhere. On Swinden Moor and at Nappa the continuation of the cross-folding systems produces a dome-shaped mass with quaquaversal dips. I shall refer to these strata again.

Then there is a long, sharp and well-marked anticlinal—the Barnoldswick-Thornton anticlinal—where there is much faulting and some overthrusting, with strikes on the whole steadily S.W. to N.E.

It is not too much to say that in nearly every one of the very numerous exposures in this Barnoldswick-Thornton massif, either faulting or folding of the beds may be seen, with abundant slickensiding (see Plate I., Fig. 2, and Plates III. and IV.). These beds will also be mentioned again.

Lastly there is another dome-like mass between Broughton and Gargrave, very much like the Marton-Swinden mass already mentioned. I have not included much of this mass in my work.

Thus while the dominant folding strikes S.W.–N.E., there is also folding nearly at right angles to that direction, just as is seen in the neighbouring Coal-field of Burnley. The crossing of these folds is of considerable significance in explaining the structure of the district.

The literature is already considerable.

The district is described in the Survey Memoir on the Burnley Coal-field. (Of course Phillips included it in his Geology of the Limestone District of Yorkshire.) Mr. Tiddeman has made several communications to the British Association Reports and other literature respecting the Reef-knolls in this and adjacent areas. Prof. Marr (Q.J.G.S., Vol. lv., 1899, 327–361) disputed Mr. Tiddeman's theory of Reef-knolls and proposed

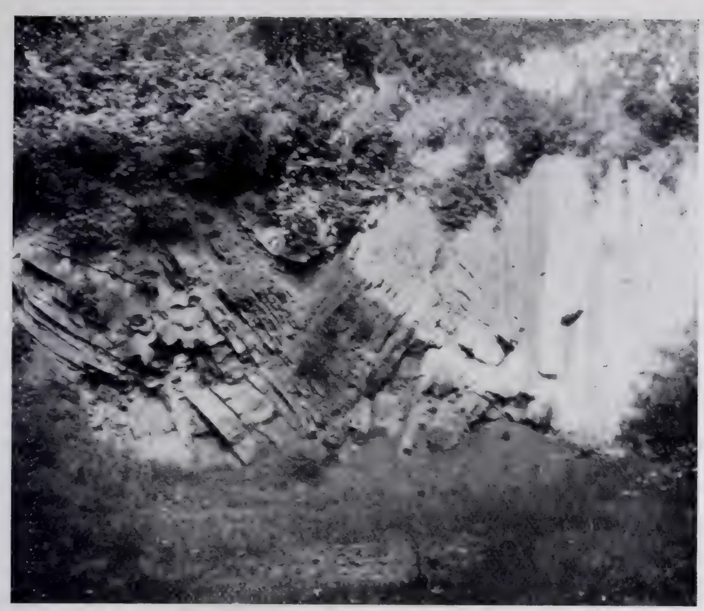


Fig. 1.

FOLDED STRATA AT FOXLEY BANK, NEAR SAWLEY, CRAVEN, YORKSHIRE.

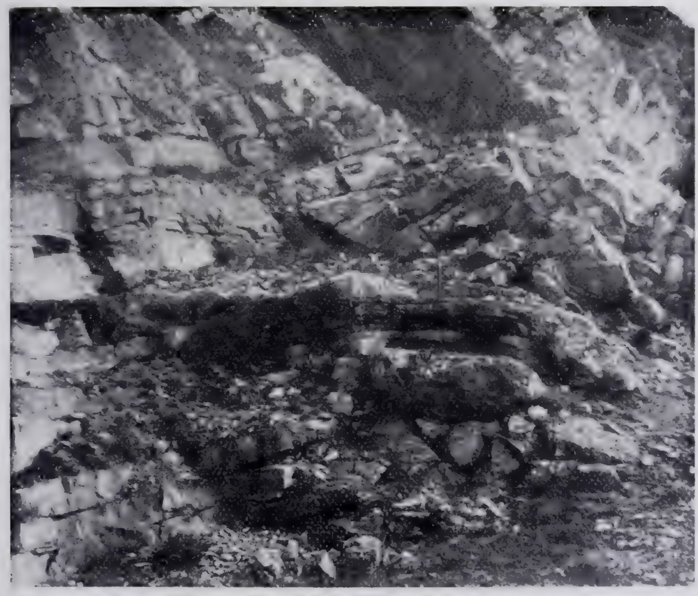


Fig. 2.

FOLDED AND OVERTHRUST STRATA AT BROUGHTON FIELDS, NEAR SKIPTON, YORKSHIRE.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate I.

one based on orogenic movements, involving probably overthrusting and repetition of beds. He brought evidence mainly from the Draughton folded area and from Winterburn, and applied it to explain the Reef-knolls of Scaleber, near Settle, of Malham, and of the Cracoe district. Mr. Tiddeman replied in a communication to the British Association, Bradford, 1900 (Geol. Mag., June, 1901).

Mr. Lomas, in an interesting paper on strike maps (British Association), illustrated his paper from the Clitheroe-Downham area.

Dr. Hind has several papers which deal directly or indirectly with these rocks (Geol. Mag., April and May, 1897 ; Trans. Edin. Geol. Soc., Vol. vii. ; Geol. Mag., Feb., 1898).

Dr. Hind and Mr. J. H. Howe, in their paper on " The Pendleside Group at Pendle Hill, &c." (Q.J.G.S., lvii., 1901). vigorously challenged some ideas which had been generally accepted. First they combated the stratigraphy of the Survey officers. The beds between the undoubted limestone massif *below* and the Millstone Grit beds *above* (with the Pendle Grit—Farey's grit of Derbyshire—at the base) and which are some 2,000 feet thick in this district under consideration, had been called Yoredale beds by the Geol. Survey (they do not use the term Yoredale on the newer edition of their maps). Dr. Hind and Mr. Howe contended that these intermediate beds have much more in common with the Millstone Grits and Ganister beds above than with the Carboniferous Limestone below, and they proposed the name Pendleside Series for these strata.

Secondly, they challenged the idea that the Craven Faults divide the Carboniferous Limestone area into two stratigraphical districts, with a succession and paleontology on the north of the faults differing from the succession and paleontology south-west of the faults.

The literature dealing especially with limestones, their nature and origin, with slight exceptions, does not especially refer to this district. The papers on Reef-knolls already mentioned and the joint paper of Dr. Hind and Mr. Howe may, however, be quoted again as dealing in some measure with this branch of the subject. On the nature and origin of limestones generally, the following literature has been of use in studying the examples in this district :—

(1) The classic paper of Dr. Sorby (Q.J.G.S., 1879), "On the origin of certain limestones."
(2) The work of Sollas on Coral Reefs, Derived Limestones, &c. ; various papers.
(3) Harker's Petrology. Geikie's Text Book, 4th edition.
(4) Rosenbusch, Elemente der Gesteinslehre, and the excellent account and discussion in Zirkel's Lehrbuch der Petrogrophie, vol. iii., under the heading "Bildung der Kalksteine."

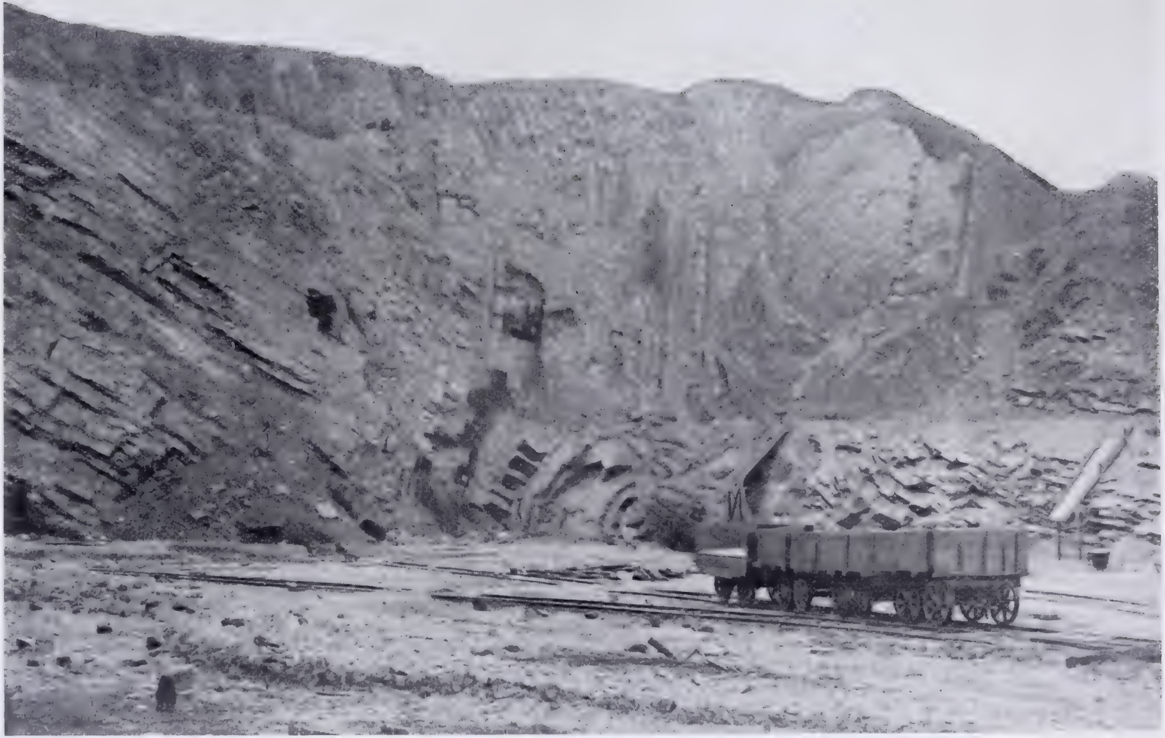
The Nature of the Limestone Rocks.

(*a*) *The white or greyish-white limestones.*

It is, of course, well known to everyone that much of the limestone rock of this Craven Lowland country evidently consists of organisms ; shells (Mollusca and Brachiopoda), Polyzoa, Echinodermata (Crinoidea and Echinoidea, and Blastoidea), and corals. The knoll masses of Clitheroe and Downham have long been a favourite collecting ground, and the shells and other fossils may often be extracted in great perfection. The limestone masses thus built up—as they often are—almost exclusively of shells are usually of the light grey (so-called white) type ; but these shell masses are not by any means confined to the detached or semi-detached masses known as knolls on the one hand, nor to the white limestone on the other.

The famous Bold Venture Quarries, near Chatburn Station, have long yielded abundance of the most perfect fossils—Brachiopoda and Mollusca (Gasteropoda, Cephalopoda, and Lamellibranchiata)—but these beds are quite half a mile from the southern edge of the beds where the knolls occur, and are thus (taking the dip as not more than 30°) at least 1,300–1,400 feet down in the series. There are other exposures in the Clitheroe-Chatburn area which are also very fossiliferous.

Again, shell aggregates are not confined to the white type of limestone. At West Marton there is a dark limestone, with



Photographed by Godfrey Bingley, Headingley, Leeds.

FOLDED STRATA IN HAMBLEDON QUARRY, NEAR BOLTON ABBEY STATION.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate II.

the "sulphury" smell on fracture, which contains abundance of Producti. At Swinden Moor, dark grey, well-bedded, almost flaggy limestone consists almost entirely in places of Chonetes and other deeper water forms. At Broughton fields there is a very black shaly limestone crowded with small Brachiopod shells, and I have no doubt other workers could multiply such instances.

Some of the shells found are rolled ones, having evidently been considerably knocked about on the shallow sea beaches before being finally entombed in the shell breccia. The occurrence of similar rolled fossils at Cracoe, Threshfield, Malham, and other very fossiliferous localities is well known. This does not seem to be the case with the shells and other fossils found in the well-bedded dark grey and blacker limestones. I have rarely found shells from these to show any trace of wear and tear.

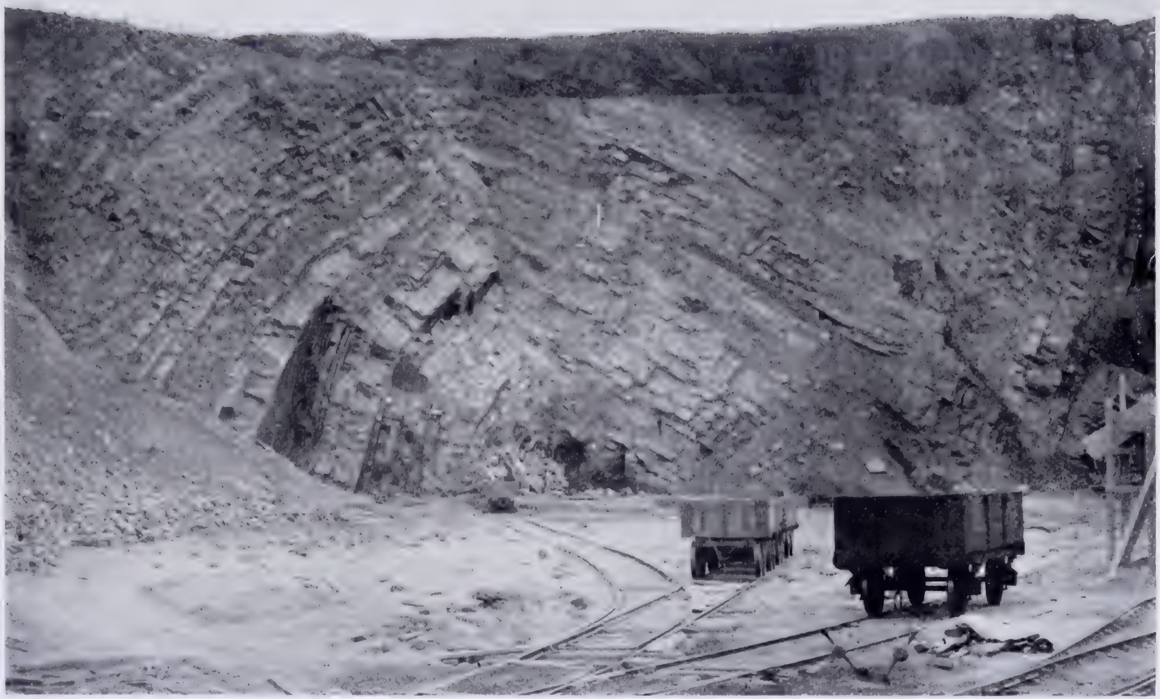
Crinoidal limestones are extremely plentiful in all parts of the district. At Twiston one of the "knolls" consists almost exclusively of crinoid stems. The stems are often indiscriminately heaped together, large stems, half inch or more in diameter, being mixed with the smallest possible fragments. And yet there is often some rude sorting according to size. It is noteworthy that in this immense mass comparatively few plates are found and the stalks seldom show that branching which is well seen in the crinoidal debris of the more shaly areas. At Worsaw—the largest and highest of the knoll masses—crinoidal debris limestones are well developed. They are perfectly well bedded—much more so than the Twiston beds—and large flaggy pieces for building the walls of the pastures have been got from the south-western exposures.

On the other side of the Worsaw knoll-mass and at Crow Hill, near Worston, the most westerly of the distinctive knoll-like masses, crinoidal fragments are mingled indiscriminately with shell fragments of all kinds, and with corals and plates and cups scattered here and there. This kind of deposit—the mixed organic deposit—is more common than a deposit made up exclusively of one class of organism. These deposits are also fairly well bedded, quite as well as the masses of white limestone in the middle of the massif and elsewhere, and quite as well as I have seen them in the thick white limestone north of the fault, e.g., in the neighbourhood of Arnside, and in Derbyshire, where there is no distinctive knoll-structure.

I have not noticed corals to be nearly so common in these Clitheroe masses as they seem to be in some parts of the Carboniferous Limestone, in the neighbourhood of Arnside, for example. One finds there enormous masses built up of Cyathophyllum, Lonsdaleia and Lithostrotion ; but that is not so in the Clitheroe district, though, of course, we find such genera as Amplexus, Zaphrentis, Cyathophyllum scattered amongst the shell and crinoid debris.

In connection with these white limestones there are conglomerates and breccias, which have been the subject of much comment and some dispute. To prevent confusion it may be well to point out that three types of breccia are found in the Craven Lowland country. First, crush breccias, like those noted by Prof. Marr at Draughton and at Winterburn ; good examples are to be seen at Broughton Fields, in the eastern part of the district, and at Foxley Bank in the north-western corner. I do not think examples are frequent. Secondly, there are the shell and crinoid breccias already noted. Thirdly, there are the limestone breccias, made up of derived fragments ; most, if not all, of these fragments are of Carboniferous Limestone stuff and must have been broken off the already solid or partly solid masses of calcareous deposit. At Worston—Crow Hill—such a breccia consists of fragments of crinoids and of echinoids, of shells, and of allothigenous bits of crinoidal stuff and solidified limestone " paste." This example seems to be interbedded with the usual shell and crinoid breccia, and there is every gradation between stuff formed exclusively of immediate organic debris, and stuff containing little else than derived lumps of matter, which was already solidified or partially solidified (cemented).

This somewhat typical breccia happens to be well seen at the front (base) of a knoll, but this is probably accidental, and as it is a fairly regularly bedded mass of limestone, the breccia belongs to the upper part of the limestone massif.



Photographed by Godfrey Bingley, Headingley, Leeds.

FOLDED STRATA IN HAMBLEDON QUARRY, NEAR BOLTON ABBEY STATION.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate III.

These grey, very fossiliferous limestones, which are usually very pure—many of them containing from 95 to 100 per cent. of $CaCO_3$—are often put down as fairly deep-sea deposits, but from fairly extensive work among them I am confident they are shallow water beds. The shells, crinoid and coral fragments are debris matter, and much of it has been rolled into its place by the waves. Hence the indiscriminate mingling of the various classes of fossils and the sorting according to size—which is not at all uncommon. The rolled fossil shells, crinoids, and single corals also show beach conditions.

The area of accumulation where these thick deposits were formed was singularly free from sedimentation of the ordinary type, though numerous shale partings at Clitheroe, Chatburn, and Downham show that such conditions were not far away, and that this clastic sedimentation sometimes prevailed over the shell-debris accumulation. The muddy habitat species invaded the region, as one would expect.

It is noteworthy that, both here and in other parts of Craven where shell and crinoid debris is found, the delicate mat-like growths of Polyzoan colonies are often seen spreading indiscriminately over shells, coral, and crinoid fragments. I have seen these Polyzoa in the middle of some of the least definitely bedded of the knoll limestones spread quite evenly and in places parallel to that which would be taken as the dip ; this occurrence proves that these limestones are successive accumulations of organic debris, and that some at least of the want of bedding is due to secondary growth and deposit of calcite matter acting as a cement and causing some part of that structureless appearance which is characteristic of these limestones.

When we remember that these deposits are formed of shells and shell-fragments of various sizes, of crinoids, and of corals mixed together ; when we remember that the material of which they are composed is easily dissolved in natural waters and easily deposited again, we do not expect the same regularity of stratification that is seen in some other strata. I believe the rocks—both those in the massif and those forming the outstanding knolls—are in this respect much like the limestones of Derbyshire, of North Yorkshire, and of other localities where there is no question of knoll formation.

The nature and origin of these limestones is very closely mixed up with the problem of the origin of the Reef-knolls incidentally referred to already. The views of Mr. Tiddeman are so well known that they need no recapitulation, and the criticisms and suggestions of Prof. Marr, Mr. Dakyns, Dr. Hind, and others will be well known to members of this Association. I offer some remarks and suggestions here and in a later part of this paper.

There are four well-marked knolls in the Clitheroe-Downham district and one semi-knoll. They may be called, proceeding from east to west, Twiston Knoll, Sykes Knoll, Gerna, Worsaw (the highest of all), and Crow Hill. They stand out as Peninsulas or islands in the lowland, whih is mapped as " shales with limestones " by the Survey officers. Worsaw reaches 700 feet, that is about 300 feet above the level of the lowland plain. It is noteworthy that there is every gradation between the slight cape of the great limestone massif—as at Worston (Crow Hill)—through the well-marked Sykes peninsula to the " island " of Gerna.

The general dip of the limestones here is synchronous with that of the shales in the district, which lie between the massif and the masses of grits in the Pendle range—the rocks of the massif itself have the same general dip. The dips in the knolls themselves sometimes show something of the quaquaversal—this is especially marked in the case of Gerna—and thus the strike lines become elliptical or circular.

The dips are perfectly well marked and, as already mentioned, in one part of Worsaw Hill the limestone becomes particularly well bedded.

It is noteworthy that no similar masses occur on the north-western side, and that the organic breccia-like character of the limestone has gradually given place to the well-bedded more fossile limestone formed of fine organic debris, and which is the normal limestone in the greater part of the area treated of in this paper. The breccia-like character is still maintained towards the middle of the massif and here the scar and mound-like character is still seen. In the northern part of the anticlinal we have sharply folded strata instead of the massive bulges of the knoll area. It is thus clear that the knoll-structure is a function of the coarse organic breccia, but this rock does not always produce a knoll. It has already been pointed out that much of the whole anticlinal is made up of the same stuff, and so is limestone in Derbyshire, North Yorkshire, and Westmoreland.

At Newsholme there is a light grey, very fossiliferous limestone, with very fine fossils and all the characteristic textures of Reef-knoll limestone, but it would not be called a knoll in the same sense. The fauna is quite different from that of the shales and muddy limestones of the district in which it occurs. I have obtained the following :—*Amplexus coralloides*, *Spirifera lineata*, *Rhynconella pleurodon*, *R. pugnus*, *R. acuminata*, *Terebratula* (*Dielasma*) *hastata*, *Productus* (several species), *Euomphalus pugilis*, *E. catillus*, *Macrocheilus imbricatus*, *Fenestella* (two or three species). Here is the characteristic fauna of the knolls in a district where the muddy limestones and shales are dominant, and yet the mass does not make a knoll. The fauna of the district around is very different (Plate V., Fig. F).

At Fogga—on the Skipton-Hellifield road—are faulted-up masses of the same partly confusedly-bedded organic debris, and again the rolled fossils are common. The fauna is the same. Secondary calcite deposit is again well seen. Here a knoll-mass is a function of organic breccia formation and of orogenic movement. Here we find *Dielasma hastata*, *Spirifera glabra*, *Productus giganteus*, *Zaphrentis cylindrica*, &c.

(*b*) *The Carboniferous Limestones of the eastern part and the limestones in some of the parts coloured "shales with limestones."*

These limestones are well bedded, and often quite flaggy and are usually dark-grey to black in colour. The uppermost beds are readily traced across the area, because the Pendleside shales, with their characteristic fauna, are seen to lie conformably on the limestone strata all along the southern edge of the anticlinal system.

The fauna of these Pendlesides is well characterised by *Posidonomya Becheri*, *Posidoniella lœvis*, *P. minor*, *Aviculopecten papyraceus*, *Orthoceras sulcatus*, &c. These beds, with this fauna, are seen at Pendle, Barnoldswick, Salterforth, Earby, Thornton, and Elslack dipping off the massif. Hence we may take the beds as occurring immediately below these shales and thin limestones as the top beds of the Carboniferous Limestone series.

The limestones become much more "shaly" and shale bands separate the different limestone bands very frequently. A few characteristic examples may be noted.

The south side of the Thornton anticlinal.

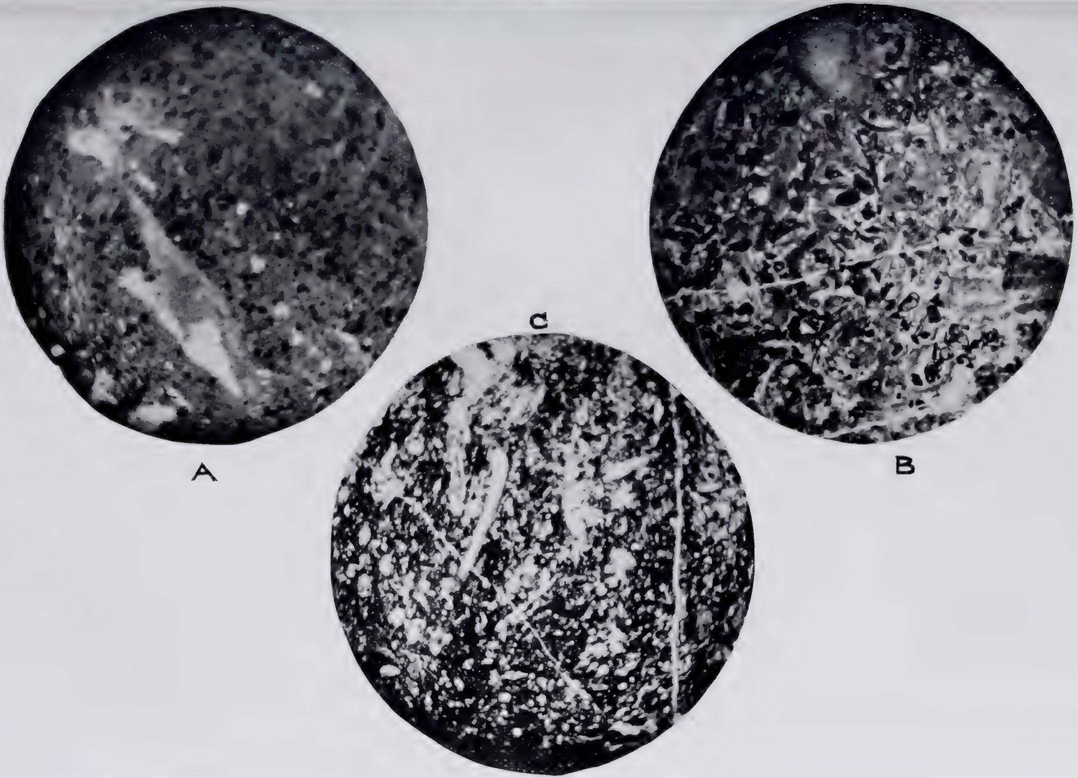
At Rain Hill there are hard dark-blue and grey limestones with shale partings. Dipping S.S.E. at about 60°. The dip varies along the extensive cutting which runs along the strike, and at one end the beds show some rolling. The fossils are crinoid stems, plates and spines of *Palœchinus*, *Syringopora geniculata*, *S. distans*, *Zaphrentis* sp., *Productus semireticularis*, *Terebratula* sp., *Semiluna ambigua*, *Spirifera* sp.

Much of the limestone is a fine broken shell breccia and it is now very crystalline.

At South Field—nearer the middle of the anticlinal—we have dark-blue hard limestones, with much ironstone—iron carbonate and iron oxide. The limestones are well bedded and fossiliferous. There are partings of dark calcareous shale, with numerous fossils. The dip is about 25° S.S.E. *Syringopora* is again very common. Crinoidal stems and plates are plentiful. *Zaphrentis* occurs. *Chonetes papilionacea* and *Productus punctatus* are zonal forms which are plentiful. The strata show faulting (see Plate IV., Fig. A, for microstructure).

At Thornton Hall Brow Quarry there are dark flaggy limestones with calcareous shales. Crinoidal stems and plates are scattered in the fine *dark calareous mud*. *Syringopora* occurs again. I have obtained a *Terebratula*, but shells are very rare. Dip, 50° S.E. (see Plate IV., Fig. B).

After minor exposures at Thornton Hall and Thornton village—where there is another fault—we come to Thornton Quarry. The rocks are dark-blue and grey earthy limestones with partings of shale—almost muddy at times. As in all parts



Photographed by Peter Whalley, Colne.

A. Hard, dark Limestone. Quarry at Southfield, half-mile from Punch Bowl Inn, Earby.
B. Fine-grained, dark Limestone. Punch Bowl Hill, Thornton Road, Earby.
C. Flaggy Limestone. Road cutting, Thornton-in-Craven Church.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate IV.

of this anticlinal there is much calcite and iron oxide. The upper beds are mostly shales. Dip varies from 60° to 70° S.E. Fossils are very numerous in the shales. Among them the following are common :—*Syringopora reticulata, S. ramulosa, Lithostrotion* sp., *Amplexus Coralloides, Zaphrentis cylindrica, Z. cornucopiæ*, plates, spines—sometimes cups and heads crushed and broken—of *echinodermata*, e.g., *Archæocidaris* ; *Fenestella* very plentiful ; *Gasteropods*, very plentiful, e.g., *Eulima* sp. and *Orthis Michelini* ; *Productus punctatus.*

Exposures on the northern side of the anticlinal. At Gill Rock, flaggy, well-bedded limestones have shales interbedded. There is in this quarry more shale than limestone. An overthrust fault is seen, The fossils are the same as at Rain Hall and Thornton (Plate V., Fig. D).

At Thornton Church, in the cutting in the roadway, there is a small exposure. Limestone of a muddy character gradates into calcareous shales. Dip, N.N.W. about 40°. Fossils are the usual stems and plates of *echinoderms* imbedded in a black ground mass. *Prod. semireticularis* and *P. pustulosus* are found (Plate IV., Fig. C).

Three quarries at Broughton Fields show massive, well-bedded dark-blue limestone, with dark calcareous shale partings. The shales are seen to be studded with round and elliptical colonies of *Syringopora.* The growing point or growing circle may be seen usually on underlying limestone and the colony spreads out into a lenticular mass of from 6 inches to 2 feet or more in diameter. These coral masses are common and may frequently be got out fairly complete. The same corals occur in the solid limestone.

The eastern quarry of the three shows some very interesting features. First there is the black, shaly limestone, with numerous fossils in calcite already mentioned. Secondly there is a curious overthrust fault with the under strata somewhat bent over, and in connection with this there are fine systems of anastomosing calcite veins. Where the crushing is most marked the calcite veins are most numerous, and at one place a fine rhombohedral crystal of calcite is seen in the middle of dark-grey limestone, showing development of crystalline structure from the fine amorphous rock mud in a manner somewhat analogous to the development of porphyritic crystals in igneous rocks after and during devitrification.

Thirdly, there is a fine crush breccia, already mentioned in an earlier part of this paper.

There are several exposures in the somewhat dome-shaped mass between Gargrave and Broughton. The most interesting is an old quarry near Pasture House, known as Clint's Delf. The strata dip N.E. and N.N.E. at varying angles from 30° to 60°.

The sequence is as follows :—

Very massive limestones, with partings of crinoidal mud and shale.
Mud bands, full of fossils.
Thick limestones.
Shales.
Dark earthy limestones.
Dark earthy shales (bottom beds).

Exceedingly fine fossils may be obtained here. The following is a list of the commoner types :—

Many species of *echinodermata* (stems, plates, spines) in most exquisite preservation.
"Cups" of *Platycrinus* and *Poteriocrinus*.
Archæocidaris sp.
Syringopora geniculata.
,, *ramulosa.*
Zaphrentis sp.
Fenestella and *Polypora.*
Orthis Michelini and other brachiopods.
Euomphalus sp., and other gasteropods.

These beds are mapped as being at the summit of the Carboniferous Limestone, and the country to N. and N.E. is mapped as Yoredale "shales with limestones." There is, however, an exposure about three-quarters of a mile to N. of Clint's Delf where characteristic limestone fossils occur in a grey, somewhat flaggy limestone.

It is noteworthy that the whole of the district possesses the characteristic limestone geography. There are not many exposures, two or three old grown-over quarries being the only ones in a rather extensive tract, but the walls (the material for which is never carried far in this district) contain plenty of fossils. *Syringopora*, *Lithostrotion*, *Lonsdaleia*, *Zaphrentis*, and large Brachiopods are quite common. Fine sections of *Zaphrentis cylindrica* and a species of *Lonsdaleia* may be seen in some of the walls.

The Carboniferous Limestone strata may be here " rolling," and may really extend to the upper part of Swinden Gill, and perhaps to Otterburn.

It seems quite likely that these shales with limestones are simply Upper Mountain limestone beds where the shales begin to play a more important part, indicating some difference in deposition as we go north-east.

We now come to the Gisburn and Marton beds, the northern limb of the opened-out Clitheroe anticlinal. At Gisburn there is a very well-marked anticlinal, striking S.W. to N.E. On the south-eastern side there are small exposures showing the dip at What Close, New Ing, Stock Beck Bridge, and Brogden Beck, but good working sections for fossils are not easy to find. Crinoid stems and plates are found, those of *Palæchinus* being plentiful. *Syringopora ramulosa* and *S. geniculata* also occur. I hope to deal with this southern part of the district more fully in a subsequent paper.

On the N.W. side of the limb exposures are more plentiful. Beginning at Gisburn, there is a good exposure below the railway station. Dark shales and thin flaggy limestones dip at an angle of nearly 30° N.N.E. Crinoidal fragments, *Zaphrentis* sp., and *Syringopora* sp. occur. Also *Productus scabriculus*, *Athyris ambigua*, and other brachiopods. The limestones are the usual five-grained dark stuff. The dip is seen at many points in this district and is fairly constant, between 20° and 30° N.N.E.

Near Gisburn Old Toll Bar on the Skipton road there are massive dark-blue well-bedded limestones with very thin shale partings. The strata dip almost due north at 20°. Fossils are very scarce in these beds, but the walls close by, which are doubtless from the quarry, contained weathered out crinoid stems and plates, shell fragments, and polyzoa.

There are some interesting exposures higher in the series in the Stock Beck cuttings near Painley Farm and Crow Park. A new cutting in a field close by helps to complete the series.

The strata are a succession of limestones and shales with thin sandy fossiliferous beds. The dip varies from 20° to 30°. The strike of the beds is slightly north of east by south of west. The order is as follows :—First, massive, hard dark-blue limestone with overlying thin shale bands. Then fine dark-blue limestones weathering grey. Fragments of corals, and crinoids. *Productus* sp., *Fenestella* sp. quite plentiful on weathered surfaces. Next are dark earthy limestones and shales with the usual smell. They are exceedingly like those at Thornton Church, both in appearance, method of fracture, smell, and fossils. Above this there are dark shales, with occasional crinoids and *Zaphrentis* sp. (very common). There are some interesting bands of crinoidal debris, full of stems and plates ; the stuff is quite a mud, and the fragments come out almost exactly like those at Broughton.

Some of the forms are fossilised in gritty "mud," some in iron oxide, and some are calcareous.

One seems to find this same crinoidal mud nearly everywhere towards the top of the limestone series. The finest example is the one near Broughton already referred to.

Passing further north and up in the series, we reach the beds of the Pendleside group at Castle Haugh, the boundary being probably near the highway at Middlebreaks Farm.

No base of the limestone is seen anywhere in this district but the thickness exposed at Gisburn clearly amounts to over 2,800 feet approximately. The dip is almost constant in direction for about one and a quarter miles and averages 25°. There seems to be no chance of repetition of beds. Hence the thickness of the strata here would be $1\frac{1}{4}$ miles × sin. 25° = 6,600 feet × ·423 approximately = 2,800 feet.

There are no exposures in the neighbourhood of Horton, but in a pump well at Horton Manor House Farm, the usual dark limestone and shale were reached.

At Newsholme there are some good exposures which show that the boundary of the limestone has shifted to N.E. much further than is probable in the Gisburn district. There is an exposure just behind the first farm on the Settle highway, about quarter of a mile from Newsholme Station. Massive limestones dip N.N.W. at an angle of about 20°. Shale beds are very subsidiary. I have obtained only crinoidal debris here.

Across the Ribble from Newsholme lies Paythorne. Here is a drift-covered country and exposures are few. A boring for water at Carholme Farm has been recently carried to a depth of 72 feet.

25 feet drift (clay with grit and limestone boulders).
47 feet dark soft shales.

The shales are very fissile, micaceous, and very fossiliferous. I have got a good collection here. Amongst others the following are common :—

Granatocrinus Derbiensis.
,, *ellipticus.*
Orthis Michelini.
Strophomena rhomboidalis

and crinoid stems and plates.

The presence of *granatocrinus* would seem to place these strata in the Limestone Series. They are mapped as shales with limestones on the one-inch map.

Further eastward we come to the somewhat dome-shaped mass which rises to 700 feet in the hills of Marton Scar. Here there is a departure from the simple anticlinal system of Clitheroe and Gisburn. Exposures are quite plentiful.

A quarry is opened near the kennels on the Marton side of Gledstone Hall. The strata dip slightly S. of east at an angle of 30°. they are curiously folded over in one part of the quarry. Perhaps this is a surface disturbance due to glaciation. The strata are broken in the middle of the exposure but bent at the upper end.

The succession is as follows :—

Muddy shales with thin limestones, 6 feet.
Limestone, 1 foot.
Muddy shales, 1 foot 4 inches.
Limestone, 1 foot 6 inches.
Shale 4 inches.
Massive hard, dark-blue limestone.

Fossils are fragmentary and occur mainly in the shale bands. There are abundant crinoid stems and plates. I found one stem with a perfect Pentagonal Section. A broken cup of ? *Platycrinus* was found. *Zaphrentis* is common (*Z. patula*, *Z. Phillipsi*), *Orthis Michelini*, &c. (Plate V., Fig. E).

A little further north we have good exposures at Skelda and Marton Scar. This is the only part of the district where the limestone forms scars. The strata strike N. and S. with a well-marked easterly dip, which varies slightly, on the whole diminishing as the strata are traced eastward.

In an old quarry near Skelda Wood there is a fine exposure of strata, probably corresponding with those of Gledstone Kennels.

The strata in the quarry are as follows :—

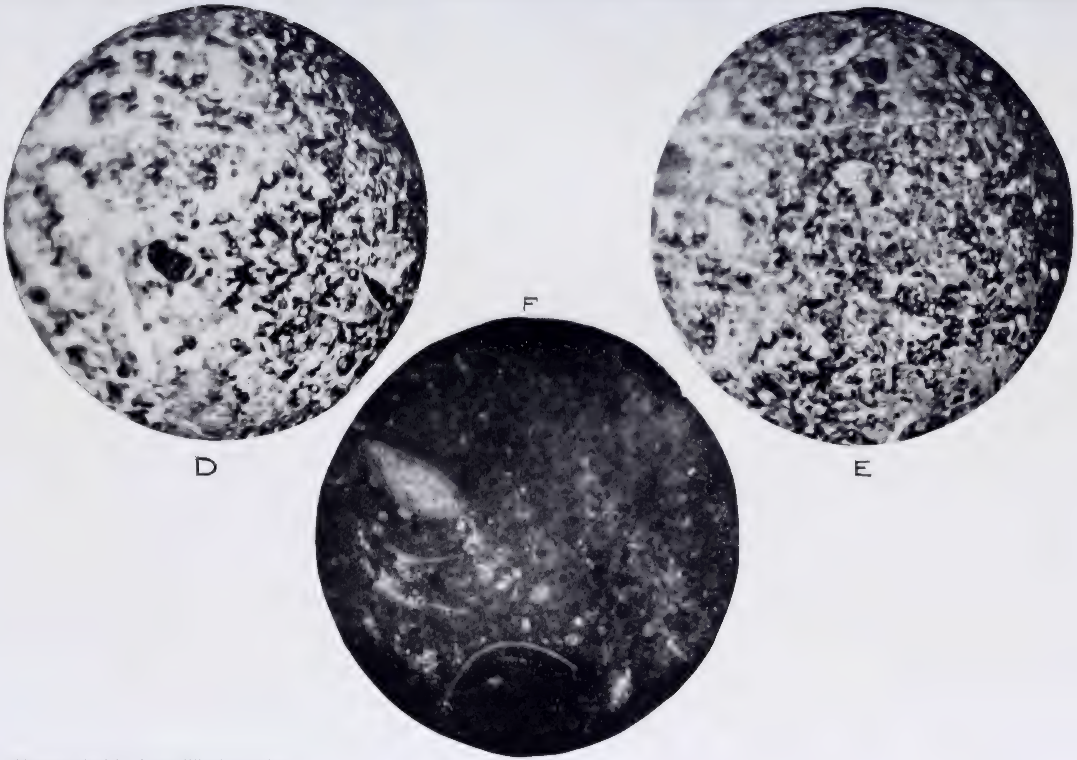
36 feet solid limestone, with thin shale partings.
1 foot shale.
9 feet limestone.
2 feet shales.
9 inches limestone.
6 inches shales.
1 foot 3 inches limestone.
1 foot 6 inches shales.
3 feet limestone.
Shales, base not seen.

The dip is nearly due east, 20° to 24°.

The shales with limestones are here succeeded by this massive limestone, which forms distinct scars.

The shale beds are black, very friable, weathering grey and yellowish on the edges. They are packed full of fragments of *Echinodermata*—stems, plates, spines. I also found *Zaphrentis* sp., *Euomphalus pugilis*, and *Orthis Michelini*. Fragments of *Productus pustulosus* (?) were found. Also fragments of a small, irregular, ribbed bivalve are quite common in these and the Gledstone beds ; it is very suggestive of a small ostrea. The massive limestones are crinoidal and shelly. *Productus pustulosus* and other fragments were obtained.

Following these strata eastwards a series of exposures may be seen on the scars. The dip remains about the same, until



Photographed by Peter Whalley, Colne.

D. Limestone, much stained with Limonite. Gill Rock, near Barnoldswick.
E. Black Limestone. Gledstone Kennels, near Gledstone Hall, Craven.
F. "White" Limestone. Slack, near Newsholme.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate V.

the quarry on the highway is reached, where it is about 10°. The strata are continued on the east side of the highway and are exposed in three or four small scars and an old quarry, then they are lost beneath drift on lower ground. The rocks in the roadside quarry are very massive, dark-blue, well-bedded limestones, containing *Productus giganteus*, *P. semireticularis*, crinoidal stuff, and *Syringopora* sp.

The total thickness exposed is about 800 feet, and the shales with limestones are at the base.

Further N. there are exposures on the S.W. side of Swinden Moor, where the strata dip E., N.E., and almost due N.

At Swinden Moor Head there are massive limestones of the grey type, rather flaggy, and with numerous shale partings. Here I obtained stems, plates, and spines of *Echinodermata*, *Zaphrentis* sp., *Fenestella* sp., *Chonetes papilionacea*, *Productus pustulosus*, *Pr. punctatus*.

At the Nappa end of Swinden Moor there are further exposures. Massive limestones dip N.N.W. at an angle of 30°. The general sequence here is—

Dark, hard massive limestones.

Soft black shales, with thin crinoidal limestones.

Massive, dark-grey limestones.

Crinoidal fragments stand out on the weathered surfaces and great numbers of the ubiquitous stems, plates, and spines occur in the shales. I obtained one broken " head " of *Platycrinus*. *Syringopora geniculata* and *S. ramulosa* are common. I also obtained *Orthis Michelini*, *Athyris* sp., *Productus scabriculus*, ? *Macrocheilus* sp., *Euomphalus* sp.

Fenestella is very common in the soft shales.

There are thus two *chief* types of limestone in the district, one the irregularly bedded masses of Obvious Organic Material and showing beach accumulations free from much ordinary sedimentary matters. The other is mainly made up of Amorphous Detrital matter derived from the mechanical wear and tear of the hard parts of organisms, aided by partial solution probably. In some cases the amorphous material has again taken on the crystalline character and some fine-grained sediments have become masses of semi-crystalline limestones. There are gradational types between these two extremes.

It thus seems that we have the coming in of the change to the northern type of Lower Carboniferous deposits, already shown in the eastern part of the Lower Craven area. Not only is there a marked change in the character of the limestone, but, as might be expected, there is a change in the fauna. Instead of the abundant *Rhynconella* (*pleurodon*, *pugnus*, *acuminata*), *Spirifera* (*bisulcata*, *glabra*, *lineata*, *striata*), with *Amplexus coralloides* and *Lithostrotion*, *Cyathophyllum*, we get more of those forms which are common to the Pendleside Series, e.g., *Athyris ambigua*, *Orthis Michelini*, *Productus scabriculus*, and *P. semireticularis*, with an exceedingly abundant development of *Syringopora* (three species), and of *Zaphrentis* (*Enniskilleni*, &c.).

The strata under consideration, with the succeeding formations—Pendleside Series, Millstone Grits, and Lower Coal Measures afford an excellent illustration of Lord Avebury's principle. His experiments in mountain building showed that when a series of formations are thrown into a common mass of folds, the lower strata show most folding, with the sharpest dip, &c. This may well be seen by tracing the beds from the middle of the Clitheroe anticlinal through Pendle to Nelson.

It is similarly seen when passing from Thornton through the Carlton synclinal and the Lothersdale anticlinal to the next synclinal of Reedshaw Moss.

There is thus extensive folding and faulting seen amongst the Sedimentary Limestones of the complex anticlinal (and the same holds for the small, sharp Lothersdale anticlinal), but it seems obvious that there would be some difficulty in accommodating the thickened beds of "massive" shell, &c., deposits to such a system of internal folding. And in this obvious difficulty it seems there may be an explanation of at least one type of reef-knoll. It is important to notice that known faults accompany three out of four of the knoll-masses of Downham in such a way as to suggest that faulting has some connection with the actual form of these knolls.

INGLEBOROUGH.

PART IV.* STRATIGRAPHY AND PALÆONTOLOGY OF THE SILURIAN.

BY T. McKENNY HUGHES, M.A., F.R.S., F.G.S., WOODWARDIAN PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF CAMBRIDGE.

"Each country ought to be described without any accommodating hypothesis, according to the type after which it has been moulded. But, in comparing the unconnected deposits of remote countries, we must act on an opposite principle; learning to suppress all local phenomena, and to seize on those only which are coextensive with the objects we attempt to classify." Sedgwick.†

I am endeavouring to follow this good advice, and, while offering a tentative correlation of the various subdivisions of the Silurian rocks seen under Ingleborough with those of other areas, to avoid forcing a foreign nomenclature upon our district. In the case of the lowest divisions of the system, we shall see more clearly as we follow the details of the classification that we cannot identify bed for bed even within the limited distance from Ingleborough to the next outcrop of Silurian on the north, where the Rawthey and its tributaries have cut down to and exposed several clear sections in the Silurian rocks, but, if we regard the whole of the series which occurs at the base of the system, we find that it can be correlated with equivalent beds much further afield.

In our examination of the palæontology also, we must bear in mind that a small difference in the character of a deposit often determines what forms of life may be expected. We see this upon any shore. Cockles and mussels and whelks and purpuras, all have their own peculiar habitat. Yet, as an accidental occurrence we find a creature that loves the mud drifted away on to the sand, or one that lives on stones carried on to a mud flat. So in the rocks *Trinucleus concentricus* is found in shale, but *Trinucleus seticornis* more commonly in sandy beds; yet they are contemporary and are often found together. When the sand was carried over the mudflats where certain Graptolites thrived they had to go or die, but when mud settled there again they or their representatives returned. Some of the common Silurian fossils, such as the smooth Pentameri, have a very short range in time, others, as *Cardiola interrupta*, run right through the greater part of the Silurian.

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* Continued from Proc. Yorks. Geol. Soc., vol. xv., p. 371. That part, pp. 351-371, should have been numbered Part iii.

† Life, vol. i, p. 297, Trans. Geol. Soc., ser. ii, vol. iii.

Therefore when we are applying the palæontological vernier to our scale of rocks we have various problems to solve before we can trust the first results at which we appear to have arrived, especially when we are making use of negative evidence. When we fail to find the characteristic fossils of an otherwise well-marked horizon, we must inquire whether the deposits in which those fossils were found have under locally varying conditions of sedimentation gradually changed from coarse to fine or fine to coarse, so that synchronous deposits carrying different forms of life occur in adjacent areas. Sometimes we can explain the absence of the fossils we expected to find by supposing that, without any discordance, sedimentation ceased over the area under examination, so that the deposit in which those fossils do occur has no equivalent in time in the area under examination, but has thinned out to nothing before it reached it. This of course implies that beds representing it, or part of it, may be expected in the intermediate area.

We should, for the practical working out of the geology of a district, classify by the more obvious petrographical characters, and then identify by palæontology, but petrology and palæontology should each be kept subordinate, as the handmaid, not the mistress, of stratigraphy.

In the preceding part of this paper I discussed the question of what we should take as the base of the Silurian, and gave a general sketch of the whole series, with a view to determining what part is represented under Ingleborough. I now proceed to examine these in greater detail.

Above the irregular and ill-defined deposit which we have spoken of as the basement bed, we found thin variable bands, not identical in any two sections under Ingleborough, and, though showing points of lithological and palæontological similarity with many of the sections at the same horizon further north, nowhere exactly represented in them.

It may be useful, therefore, to ask what we might, from analogy, have expected to find here before we examine in detail what we do see.

I give two sections, one of which (Plate VI.) shows an almost unbroken succession from the Bala Beds to the bottom of the Coniston Flags, and the other (Fig. 1) illustrates the way in which we generally find these easily crushed and faulted beds cut up and repeated, where they come out from under the Carboniferous Fells north of Ingleborough. When such beds are highly inclined, it is almost impossible to detect sharp plications and displacements, and we must always entertain the idea that the beds we miss may be nipped out by faults.

The first section to which I refer (Plate VI.) is the most complete that I know of in the lower beds of the Silurian and the upper beds of the Bala series of our district. A detailed description of this section, with full lists of the fossils which occur at the various horizons, is given by Messrs. Marr and Nicholson in their valuable paper on the Stockdale Shales.* This section gives a sample of the material which was being laid down on the north side of Ingleborough while the Austwick sediments, which we have been describing, were being spread over the south side. We have found an immense thickness of felspathic slates with subordinate grit in Chapel-le-dale, and inferred that there were more of them exposed to denudation when the lowest beds of the Silurian were being formed. So also in the northern section we see a still greater thickness of felspathic mud such as might be derived from the volcanic series. Moreover, each and all of the finer beds at the base of the Silurian are much thicker in the northern area.

In the Spengill section we have the Lower Coniston Flags passing down into hundreds of feet of Pale Slates. These are generally gray with red bands, and at one horizon yield a beautifully striped rock. The graptolites which have been found in

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* Q.J.G.S., vol. xliv., 1888, p. 654.

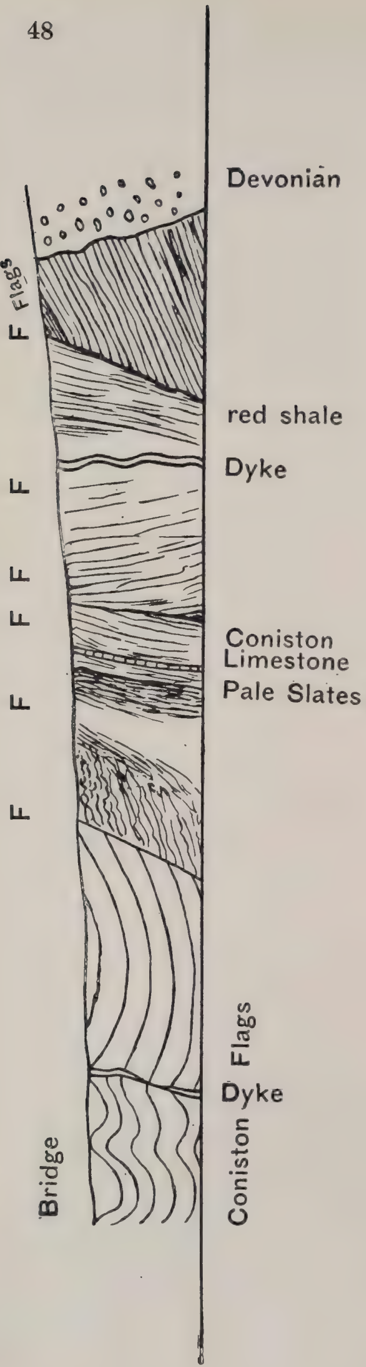
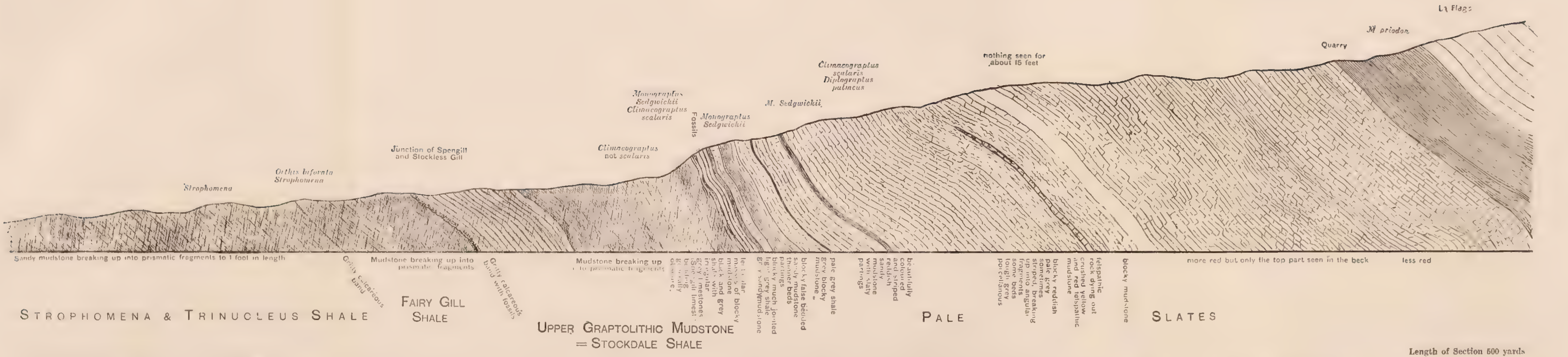


Fig. 1. SECTION IN WHINNY GILL: UPPER PART OF CROSS HAW BECK, SEDBERGH, YORKSHIRE.

this striped band are referred to *Monograptus Sedgwickii* Portl., while immediately above it *Climacograptus scalaris* His., and *Diplograptus palmeus* Barr. occur.

There are some close-textured beds consisting of the finest felspathic material reset into a porcellaneous rock suggestive of the metamorphism of the more susceptible volcanic material. One mass seems to be a dyke, but in the field can hardly be distinguished from some portions of the rock above mentioned. Near the base there is a band of false bedded sandy mudstone which is the only indication of proximity to shore throughout the series. This passes down by the intercalation of bands of shale into the Stockdale Shale, which here consists of a fine sandy shale breaking up into finger-like prismatic fragments. At the base there is a gritty calcareous band with fossils, and at the top there are irregular massive blocky mudstones and black and grey shales with lenticular beds of grey fossiliferous limestone, to which I have referred as the Spengill


Lc Flags
M priodon
Quarry
nothing seen for about 15 feet
Climacograptus scalaris Diplograptus palmeus
M. Sedgwickii
Monograptus Sedgwickii Climacograptus scalaris
Fossils
Monograptus Sedgwickii
Climacograptus not scalaris
Junction of Spengill and Stockless Gill
Orthis biforata Strophomena
Strophomena
Sandy mudstone breaking up into prismatic fragments to 1 foot in length
Gritty calcareous band
Mudstone breaking up into prismatic fragments
Gritty calcareous band with fossils
Mudstone breaking up into prismatic fragments
irregular grey limestones (Spengill limestone)
irregular shale with black and grey mudstone
irregular masses of blocky mudstone
grey sandy mudstone
light grey shale
blocky much jointed
blocky false bedded sandy mudstone thinner beds partings
pale grey shale grey blocky mudstone
beautifully coloured and striped reddish sandy mudstone with slaty partings
blocky reddish pale grey sometimes striped, breaking up into angular fragments some beds tough grey porcellanous
felspathic rock dying out crushed yellow and red felspathic mudstone
blocky mudstone
more red but only the top part seen in the beck
less red
Strophomena & Trinucleus Shale
Fairy Gill Shale
Upper Graptolithic Mudstone = Stockdale Shale
Pale Slates
Length of Section 500 yards

Proc. Yorks. Geol. Soc., Vol. XVI., Plate VI.

SECTION FROM LOWER CONISTON FLAG QUARRY IN SPENGILL TO BELOW JUNCTION OF SPENGILL AND STOCKLESS GILL, NEAR RAWTHEY BRIDGE, SEDBERGH, YORKSHIRE.

Limestone. Below this comes the Fairy Gill Shale, which passes down into the Coniston Shale with *Strophomena* and *Trinucleus* fairly abundant in it. The Fairy Gill Shale also breaks up into prismatic fragments which are larger and larger as we descend, until they are more than a foot in length.

In this lower series there is also a fossiliferous calcareous gritty band, which is the bed referred to by Harkness (Q.J.G.S., xxiv., 1868, p. 301) where he quotes me for the occurrence of Bala fossils in calcareous shales. Those fossils were not found in the calcareous beds in the Graptolitic Mudstone but in the calcareous band shown in the section (Plate VI.) in the upper Bala or Fairy Gill Shale.

The other section is that seen in Whinny Gill which runs down into Cross Haw Beck, Sedbergh. This section traverses the same beds as those seen in Spengill, but the rocks are faulted and folded to such an extent that it would be impossible to work out the succession from what is there seen.

The Spengill section, however, has fortunately escaped this tangle of faults and folds, and gives us a sequence by reference to which, notwithstanding differences in thickness, &c., we may fit the beds seen on the south side of Ingleborough into their proper place.

THE GRAPTOLITIC MUDSTONE OR STOCKDALE SHALE.

The Graptolithic or Graptolitic Mudstone was first cut off from the top of the Bala Beds by Harkness and Nicholson,* but it is clear from their lists of fossils that they had collected from beds far below what was afterwards included in the Graptolitic Mudstone, as well as from beds in what is now recognised as the lower part of the Silurian. Therefore the next step in the history was the limitation of the Graptolitic Mudstone. The lower beds, which are stratigraphically and palæontologically tied to the Bala, were called Fairy Gill or Ashgill Shale, while Mr. Aveline proposed the name Stockdale Shale for the upper part. The Graptolitic Mudstone or Stockdale Shale consists of very soft black shale with thin subordinate harder beds of calcareous sandstone or limestone. The series, therefore, yields very readily to denudation, and hence is rarely seen except in the beds of streams or in cliffs. The bands of limestone or calcareous sandstone generally occur quite at the top of the series. In the limestone seen just above the waterfall at Wharfe Mill Dam, Dr. Marr detected *Phacops elegans* Boeck. and Sars., which characterises a zone in the Scandinavian Silurian. Among other fossils found in this thin lenticular bed were *Petraia elongata* Phill., *Leptœna quinquecostata* McCoy, *Cheirurus bimucronatus* Murch., and *Encrinurus punctatus* Brünn. The Spengill limestone also has yielded the same species, with the addition of an *Illœnus*, a small undetermined *Orthis*, and a lamellibranch, probably *Ctenodonta*.

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* Q.J.G.S., xxiv., 1868, p. 299; xxxiii., 1877, p. 461.

From the district north of Ingleborough where the Graptolitic Mudstone is best developed many fossils have been obtained which are now in the Jermyn Street Museum, but only a few have yet been determined and placed on record. In some beds, especially in the black shales, a rich graptolite fauna occurs; in other beds, especially in the limestones and calcareous sandstones, trilobites and brachiopods are not uncommon. The list of fossils collected by the Survey* from the black shales series, and corrected by Miss Elles, is as follows:—

Climacograptus sp. like *scalaris* His.
Diplograptus palmeus Barr.
D. sp. (= *D. pristis* of old lists).
Monograptus lobiferus McCoy.
M. Hisingeri Carr. (= *M. Sagittarius* His.).
M. Sedgwickii Portl.
M. tenuis Portl.
Rastrites peregrinus Barr.

Now we must inquire whether there is anything in the character of the material of which the rocks are made up to explain the great difference in the thickness of the several beds in the Austwick section as compared with that of Spengill. In Spengill, the conglomerate is represented by a thin calcareous band, but in closely adjoining sections in the same district north of Ingleborough, the conglomerate is as strong as at Austwick, and I have already shown that there are as great variations and differences of the same kind, between the several sections in the southern district itself, as there is between the section from the south and that from the north side of Ingleborough which we are comparing. The Graptolitic Mudstone or Stockdale Shale is hardly recognisable in the Austwick section, Fig. 2, but the black shale seen close above the conglomerate is very like that seen in the same position in many of the sections on the north side of Ingleborough. A limestone is seen in the Austwick section at the base of the Pale Slates, and a fault explains why the main mass of the Stockdale Shale is lost sight of under the limestone on the downthrow side.

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* Mem. Geol. Survey, 98, N.E., p. 7.

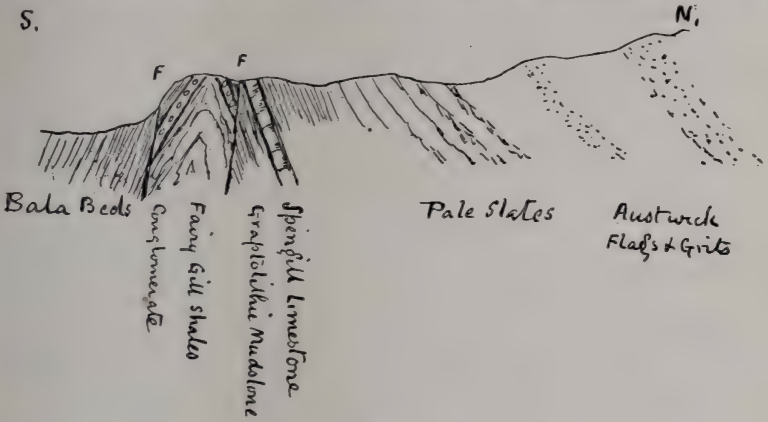

Fig. 2.

DIAGRAM IN ILLUSTRATION OF EXPLANATION OFFERED OF SECTION AT WATERFALL BY WHARFE MILL DAM.

The Fairy Gill Shale is just seen in the centre of the anticlinal arch ; the main mass being folded, and thrown down out of sight, between the two faults indicated in the section. This view is confirmed by the occurrence of *Strophomena siluriana* Dav., *Orthis testudinaria* Dalm., and other Fairy Gill fossils in the black shale under the conglomerate, and of *Monograptus crenularis* Lapw. above it. These faults and folds and changes of dip are oblique to the strike of the beds, and therefore it is impossible to indicate with precision in one section, the manner in which the absence of beds, which are of great thickness on the other side of Ingleborough, can be most probably accounted for, but, from the character of the material over the whole district, I hardly think that they can have thinned out here and therefore offer the above diagram as the most probable solution.

There still remains the discrepancy between the small thickness of what for convenience we cut off at Austwick under the name Pale Slates, and the enormous development of the similar beds in Spengill. In Spengill, however, we have not the Austwick Flags with subordinate grits, or the grits of the "White Stones" with their subordinate flags, and it may be that further palæontological evidence may enable us to explain the difference in the sediments of the two areas on the hypothesis that the "Pale Slates" of Spengill have been developed at the expense of, and are equivalent to, part of the Austwick Grits and Flags.

THE PALE SLATES.

These are on the horizon of the Tarannon Shales of which Ramsay writes (Mem. Geol. Survey, vol. iii., 1866, p. 4).

"The Tarannon Shales underlie the Denbighshire Sandstones, and by the Geological Survey were first considered to form the uppermost part of the Bala Beds, but when the maps were nearly completed, Mr. Aveline began to suspect that they belonged rather to the Denbighshire Sandstone Series, a suspicion entertained by Mr. Jukes before; and I believe at a much earlier date Professor Sedgwick had mentioned them as pale-coloured earthy slates or 'paste-rock.'"

They were described by Harkness and Nicholson (Q.J.G.S., xxxiii., p. 477, and named by them Knock Beds, on account of their excellent development in Swindale Beck, near Knock.

The fossils which they record from them are—

Monograptus priodon.
M. broughtonensis Nich.
Orthis.
Discina,

and some minute lamellibranches.

Miss Elles, to whom I am indebted for the revision of all my lists, is of opinion that the graptolite which appears above as *M. priodon* is probably the *M. Marri* of Perner.

The Pale Slates are commonly interbedded with red and greenish grey shale. The conditions of sedimentation were now beginning to settle down, so that similar deposits were distributed over large areas as compared with the banks of gravel, and pans and hollow places filled with black mud, which were characteristic of the basement beds. We still find thin beds of black shale here and there in the Pale Slates, and it is where these occur, that we most often meet with the traces of organisms; but the Tarannon Shale of Wales and the Pale Slates of our district are generally barren.

In the Pale Slates of Spengill I have found *Monograptus Marri* Perner, *M. Hisingeri* Carr., and (?) *M. Becki* Barr., but I have expressed a doubt when describing that section, p. 52, whether some of the beds which appear to be part of the Pale Slates may not rather be equivalent to portions of the Austwick Flags and Grits.

THE AUSTWICK FLAGS.

The Austwick Flags consist chiefly of sandy mudstone, with a tendency to split along the bedding into large flat masses, so that the name *flags* is appropriately applied to them in this district. The cleavage is not so strong as in the underlying Bala Series, but yet sometimes, when at a considerable angle to the bedding, it makes itself felt so far as to cause the rock to split across the bedding planes into large slabs.

Among the fossils found in these beds were—

Monograptus vomerinus Nich.
M. priodon Bronn.
M. personatus Tullbg.
M. cultellus Törnq.
Retiolites geinitzianus Barr.
Orthoceras.

Harkness and Nicholson noted that in the lower part of the Coniston Flags "a form possessing strong spines attached to the cell mouth is seen." This was probably *M. vomerinus.*

As time went on, sand was intermittently carried over this area, and indeed over the whole of the area between Ingleborough and mid-Wales so far as the Northern type of Silurian, which I have described above (pp. 355-356), extends in that direction. The beds of tough sandstone, thus formed, resisted earth movements and denudation more than the flags, and consequently everywhere stand out in bold relief, and by their obtrusiveness give an impression that there is a larger proportion of beds of coarser texture than is really the case. They were called grits both in North Wales and in the North of England by the early geologists, who always spoke of Coniston Flags and Grits, or Denbigh Grits and Flags.

Anyone who had worked chiefly among the Carboniferous rocks would be surprised at this use of the word *grit* by Silurian geologists. The Coniston Grit and the Denbigh Grit are generally very fine sandstones, although in some localities, as at Caer Drewyn, near Corwen, for instance, or at a higher horizon, in the case of the Winder Grit, near Sedbergh, the rock is made up of quartzose fragments so large that no one would quarrel with the name grit as applied to them ; but these are beds of very limited extent. It is perhaps the toughness of the rock, and its rough feel, that caused the name grit to be extended further than the texture would suggest. If the name trachyte had not been appropriated for an igneous rock it would be very applicable to our Silurian grit. The matter has been discussed on several occasions. In 1866 (see Geol. Mag., vol. iii., p. 207, footnote) I used "*Greywacke*" as a lithological term for the rough, tough sandstones so common in the palæozoic rocks, as *grit* was required for the coarse-grained rock intermediate between sandstone and conglomerate, e.g., Millstone Grit, and in 1867 Mr. David Forbes urged that the old word, Greywacke, which was no longer employed with its original stratigraphical signification, should be transferred and applied as a lithological term to rocks of the character of the Coniston grit, but the proposal was not generally accepted (Geol. Mag., vol. iv., 1867, p. 229, footnote).

The characteristic fossil is *Monograptus vomerinus* Nich., which was detected by Miss Elles on the western slope of the valley near Sowerthwaite. I had found it long ago about 170 yards north of Sowerthwaite, but in those days it was not distinguished from *G. priodon*, or when it was, was called *G. Sedgwickii*.

These beds are the equivalent of the Lower Coniston Flags, and of the Penyglog Flags in North Wales.

THE AUSTWICK GRIT A.C.2.

By-and-by there was more sand than mud, and instead of flags with subordinate beds of sandstone, we find massive sandstones with a few thin shaly partings. The tough sandstones were not susceptible of the molecular rearrangement which produced cleavage in the flags and shales, and therefore, under the lateral pressure, they buckled up into huge folds which just here often happen to present the surface of the beds to denudation, as on the top of the anticlinal arch between Crummack and Norber, so that they resist denudation both by their toughness, and their mode of occurrence. The movements of which we are speaking are pre-Carboniferous, and accordingly we find the basement bed of the Mountain Limestone abutting against the flanks of an ancient ridge of grey Silurian, the unyielding character of which undoubtedly affected the lower part of the Carboniferous to some extent during subsequent movements also. Crummack Dale has been cut out so as to expose again this undulating surface of Silurian, but how much it has been modified since the Carboniferous rocks were removed from above it, we cannot estimate with any certainty. From the evidence given above (vol. xiv., pp. 144, 145, Figs. 4, 5), in respect of the adjoining area on the South, it is probable that the bottom of Crummack Dale may very nearly represent the surface on which the Carboniferous rocks were laid down, even allowing for the immense number of boulders which lie on the limestone ledges near Norber, or are contained in the moraine mounds along the valley and open ground beyond. These are derived chiefly from the Austwick Grit.

The Austwick Grit stands out in the craggy ground west and north of Studrigg, and crops out in rough ridges by Souththwaite Wood, White Stone, and less conspicuously along the great strath from Wharfe to Swarth Moor. It is again seen on the north side of the Austwick Beck Head anticlinal, running from W.N.W. to E.S.E. on Capple Bank, and faulted at its E.S.E. end against the Moughton Whetstones, see Fig. 4, p. 57. In the adjoining valley it is well seen south of Crag Hill, where it is doubled up much in the same way as between Crummack and Norber. A tongue of the same rock is protruded in a small anticlinal fold just north of where the H in "Horton Wood" is engraved on the six-inch map. Near the "oo" of Wood there is an ill-defined grit passing up through sandstone into flags, but this I believe to be on a lower horizon, and would refer it to a gritty bed in the Austwick Flags.

Among the numerous examples of interesting rock structures to be seen in this district is that illustrated in the subjoined diagram (Fig. 3). The section occurs in a tough, slaty sandstone in Crummack Beck just above the gorge. The bedding planes are inclined at a high angle. Owing perhaps to some original difference of composition, the large divisional planes block the rock out into obvious massive beds, only the upper portion of each of which was susceptible of cleavage. However that may have been, it is clear that subsequent movements have caused displacements along these bedding planes and bent over the cleavage in accordance with the drag between the beds. I have seen the same thing in the Silurian rocks near Llanddewi Brefi, in Cardiganshire ; this was figured in the 2nd edition of Lyell's "Students' Elements," 1874, p. 590. Fig. 634.

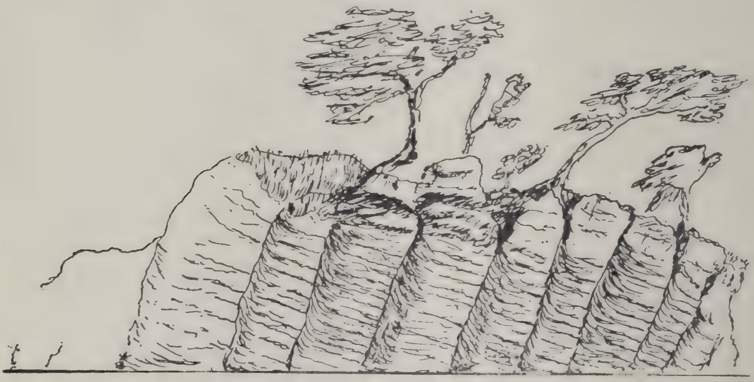

Fig. 3.

SECTION SEEN IN THE AUSTWICK GRITS ABOVE THE GORGE IN CRUMMACK DALE NEAR SOWERTHWAITE.

Length of Section, 12 feet.

THE MOUGHTON WHETSTONE.

In the north-east corner of Crummack Dale, where denudation has cut back the Mountain Limestone so as to leave the Silurian and Bala beds exposed in a bay, out of which Moughton Sike runs, and into which Moughton Lane leads to the path taking us over the Scars to Horton-in-Ribblesdale, there is a curiously weathered rock, which, from its soft, sandy homogeneous texture, has long been held in repute as a whetstone. Two systems of joints slightly oblique to one another cause it to break up into parallelograms from a few inches to a foot or so in length, with a varying breadth and a thickness of about half an inch. The colour of the rock is a greenish grey, but infiltration from the joint surfaces has given rise to thin bands of a claret-red colour, at first following the outline of the fragment, but soon, by rounding off the corners, forming a concentric circular or oval pattern.* The manner in which this banded arrangement of the iron oxides is produced has been discussed

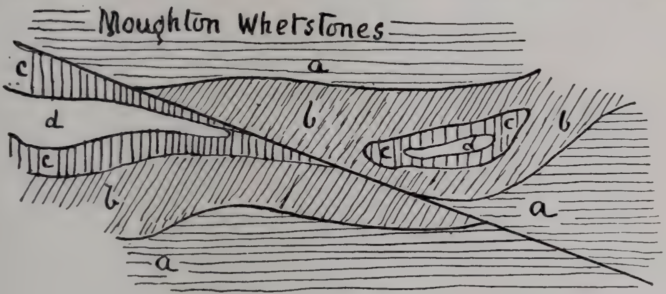

Fig. 4.

DIAGRAM SHOWING A POSSIBLE EXPLANATION OF THE MODE OF OCCURRENCE OF THE BEDS AT THE MOUGHTON WHETSTONE HOLE, ON THE HYPOTHESIS THAT THE MOUGHTON WHETSTONE MUST BE REFERRED TO A HIGHER HORIZON THAN THAT OF THE AUSTWICK FLAGS AND GRITS.

a. Horton Flags.
b. Austwick Grits and Flags.
c. Pale Slate, Graptolitic Mudstone, and Basement Bed.
d. Bala Beds.

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* See Maw on the disposition of iron in variegated strata, Q.J.G.S., vol. xxiv., 1868, p. 368, Pl. XIV., Fig. 30.

by Professor Judd* in the case of the Northamptonshire ironstone. A number of graptolites have from time to time been obtained from these beds. Miss Elles has referred them to the following species :—

Monograptus dubius Suess.
M. nilssoni Barr.
M. uncinatus Tullb.,

and considers that they indicate a somewhat higher horizon than that of the Austwick Flags and Grits, in the lower part of which they seem to occur, on the supposition that the faults shown in section, Fig. 6, have no great downthrow. If they should, on palæontological grounds,† be referred to the base of the Horton Flags, there must be a fault shifting the beds in the manner suggested in the diagrammatic ground plan, Fig. 4, p. 57.

The occurrence of *Orthoceras primævum* Forbes, which has been found in the same beds, is not inconsistent with this view.

THE HORTON FLAGS.

This series consists of a sandy mudstone, splitting into flags of enormous size (see Fig. 5). There is a rough cleavage, but when this approaches within 15° or so of the bedding planes, the rock splits along the beds and the cleavage is practically obliterated. When the cleavage predominates, the rock splits along it into rough slabs, which are found useful for building or walling. There are subordinate more sandy beds of irregular occurrence, but as rocks yielding the large flags are what are most sought in choosing a place to open a quarry, those parts were avoided in which such sandstones or grits occurred, or where the direction of the cleavage did not lend itself to the production of good flags.

In the examination of any area of cleaved rocks, it will be found that the normal cleavage is very persistent in direction and inclination—more so in direction than in inclination—and its direction generally coincides with the strike of the rocks.

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* Mem. Geol. Survey, Geology of Rutland, 1875, pp. 135-6.

† cf. Marr, Geol. Mag., dec. iii., vol. ix., 1892, p. 534.

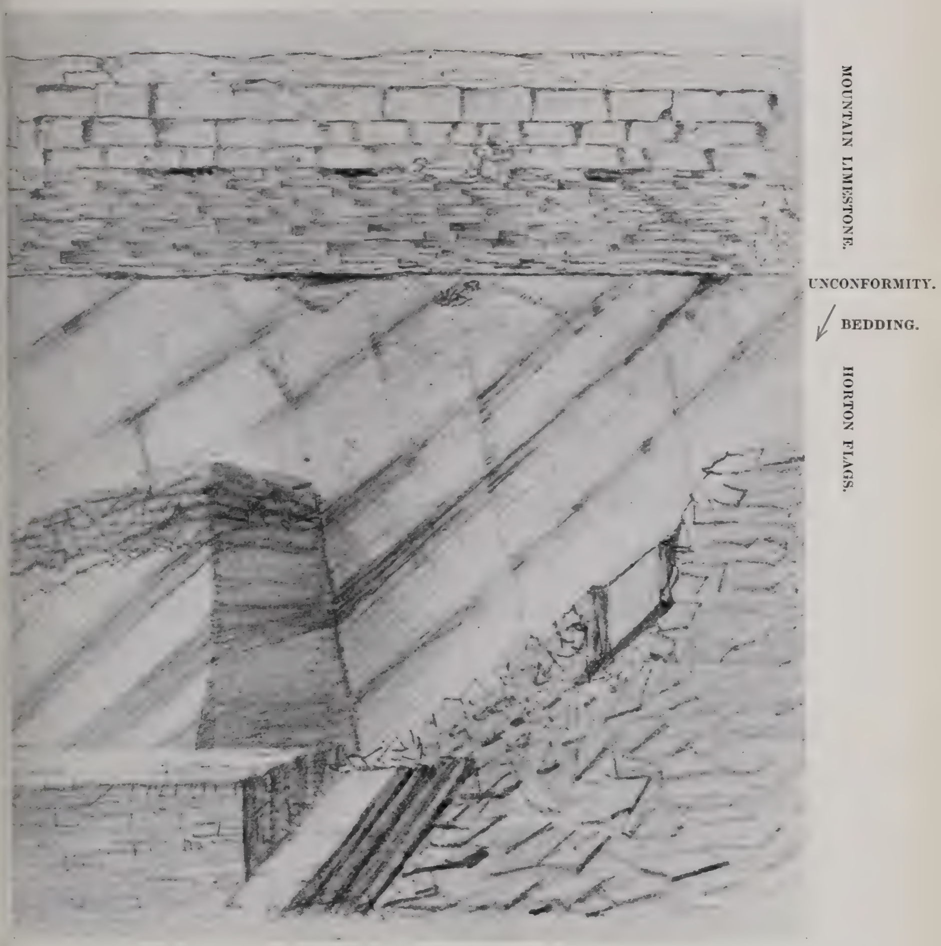
MOUNTAIN LIMESTONE.
UNCONFORMITY.
BEDDING.
HORTON FLAGS.

Fig. 5.

COMBS QUARRY, HORTON-IN-RIBBLESDALE.

Height of Section about 100 feet.

This is a very useful fact to bear in mind when mapping an area in which outcrops are scarce, and large boulders of cleaved rock common, where it is difficult to decide whether a mass which may be important for geological mapping is rock in place or merely an earth-bound boulder. If cleavage is visible, and is not normal, the chances are that it is not rock in place. Variations from the normal in direction or inclination are apt to occur where massive rocks not susceptible of cleavage occur among others in which molecular rearrangement can be produced. In such cases the tough massive rocks are thrown into folds, to which the soft compressible materials of the slates have to accommodate themselves.

The Horton Flags creep out in a synclinal fold from under the Mountain Limestone of Studrigg Scar. They pass down through thin bedded grits and roughly cleaved shales into the Austwick Grits, whose lighter colour is conspicuous in "White Stone," the name of the steep rocky ground on the south. The axis of the synclinal falls to the east, and, as its centre deepens, the northern and southern limbs spread further apart under the Carboniferous rocks of Moughton, so that the flags occupy a mile from north to south along the west side of the Ribble, and on the east side the synclinal opens out still more as the Silurian rocks disappear under the Mountain Limestone.

Seeing that the Horton Flags are the most important member of the Silurian rocks of this district, it may be convenient to describe here the three sections, which I have drawn to illustrate the Silurian succession in the adjoining valleys of Crummack Beck and Ribblesdale, although the sections carry us above and below the horizon which we have most especially under consideration.

The reader is supposed to be looking east (Fig. 6), so that the south end of the section is on his right hand. Here we see the Bala Shales (*g*), with subordinate ashes and calcareous bands (*g′*), which have been previously described. Near the barn in the line of this section, *Orthis retrorsistria* McCoy, *Leptœna transversalis* Wahl., *Trinucleus seticornis* His., *Illœnus davisii* Salt., and *Calymene blumenbachii* Brong. were found. Further north we pass over the broken ground by the waterfall, the details of which are explained, p. 51. (*f*) in this section represents the upper part of the Bala Series, above (f^1) the Bala or Coniston Limestone; (*e*) indicates the observed outcrop or inferred position of the conglomerate or calcareous rock which forms the base of the Silurian series. The highest bed of (*f*) in the line of the section is probably to be referred to the Ashgill Shale, the greater part of which is nipped out by the faults (see above, p. 51). On this lies the conglomerate (*e*), the basement bed of the Silurian, which is succeeded by (*d*) black shale, from which a few graptolites have been procured, one of which has been identified by Miss Elles as *M. crenularis* Lapw. Apparently a little above this there is the Spengill Limestone (*d′*) described above, p. 50, and then more black shale (*d*) which passes up into the Pale Slates (*c*), and these in their turn into the Lowest Flags of Austwick with subordinate grits (*b*). In the lower flags *Monograptus priodon* Bronn. and *M. vomerinus* Nich. occur, while in the higher flags, which are more sparingly intercalated in the upper part of the Austwick Flags and Grits (A, c, 2),

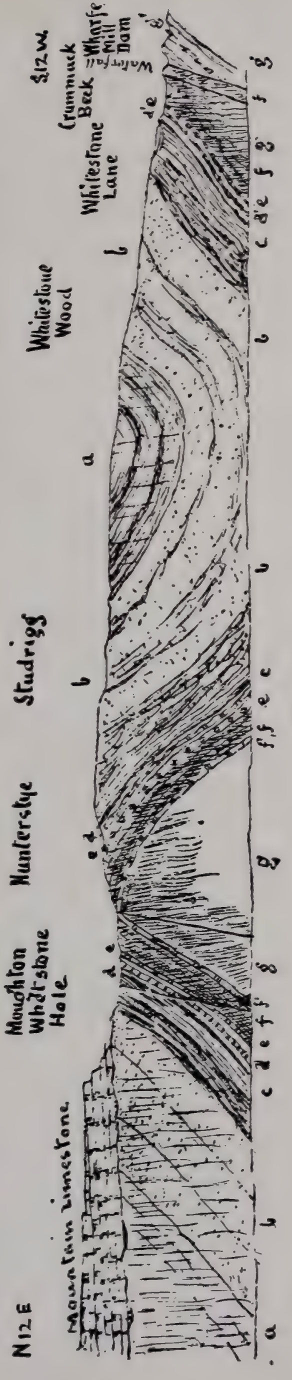

Fig. 6.

SECTION OF N. AND S. ALONG EAST SIDE OF CRUMMACK DALE.

Cyrtograptus murchisoni Carr. was found by Miss Elles in addition to the two species just mentioned.

The upper and more gritty part of this series plunges down under Whitestone Wood, and comes up again under Studrigg. holding the lower part of (*a*) the Horton Flags in a synclinal fold. The Horton Flags have yielded a few fossils in the line of the section, namely *Monograptus colonus* Barr., *M. rœmeri* Barr., *M. bohemicus* Barr., and *Orthoceras primœvum* Forbes.

All the lower beds are inferred to occur in the line of the section below Hunterstye, but little is seen except some of the calcareous beds of the Bala series. They all roll over again, and plunge under the Mountain Limestone, but are here much obscured by moraine drift and talus.

The section down the west side of Ribblesdale (Fig. 7) starts on the Green Slates and Porphyry near Bee Croft Hall Plantation, and is drawn a little way in front of the precipice of Mountain Limestone which is seen resting unconformably upon the folded Bala and Silurian rocks all the way to the south-east corner of Moughton Scar. The line of section is obscured by drift to near Gillet Brae, beyond which rock is seen almost continuously for all the rest of the section as far as Swarth Moor. At Garth House the Austwick Grits and Flags come on in a double synclinal with a broken anticlinal between them, the second or more southerly synclinal being developed under Horton Wood. At Crag Hill we have the most interesting part of the whole section, where the base of the Silurian is folded over the Bala Limestone and shale as previously described. The Graptolitic Mudstone and Pale Slate are not clearly exposed, but the Austwick Flags with subordinate grit, and in the upper part grit with subordinate flags, are well seen near Crag Hill Barn. Here also we have the best development of the Horton Flags in the whole district.

First we come to the great quarry at Arco Wood, where the flags have been cut back from the sloping flank of the valley until a clean face of rock is seen. The Mountain Limestone with a slightly uneven pockety base rests unconformably upon the upturned flags. It was near the northern end of this quarry that I found the only specimen I have seen from this district

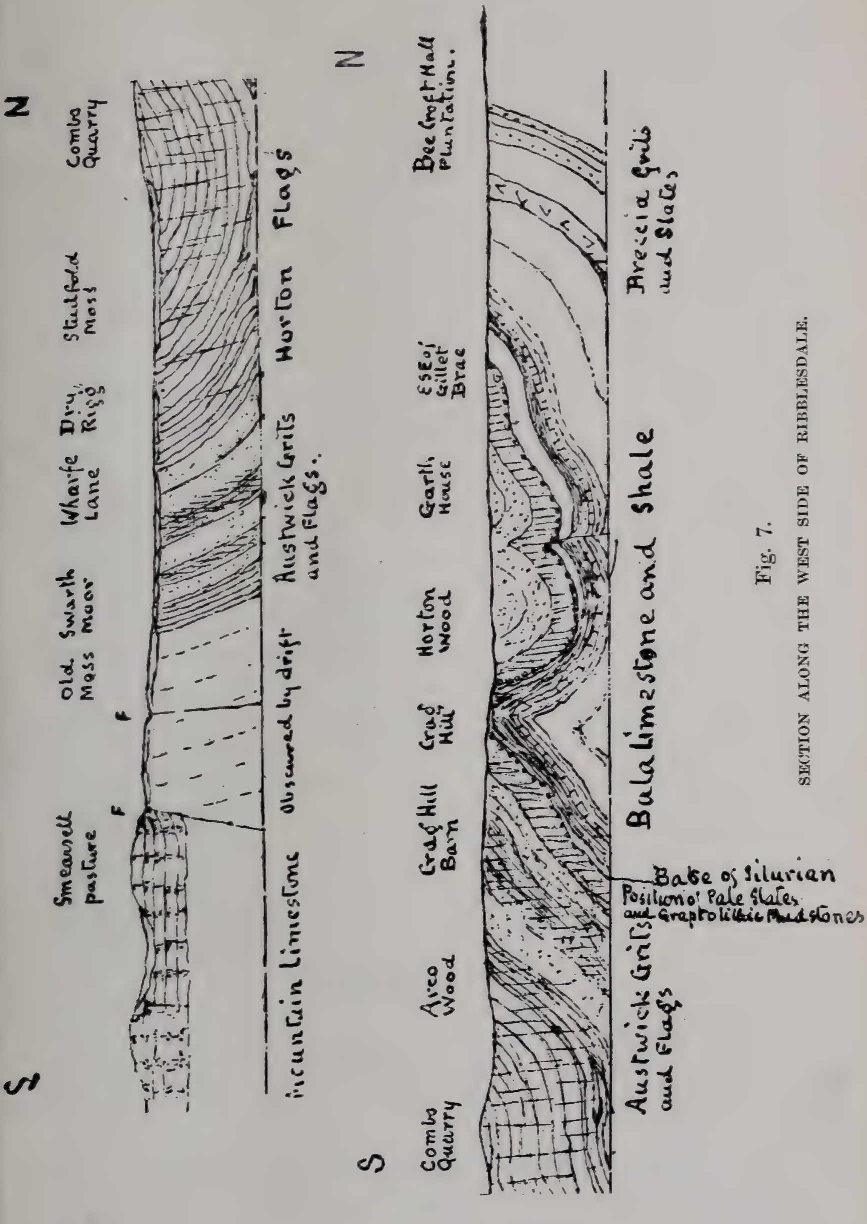

Fig. 7.

SECTION ALONG THE WEST SIDE OF RIBBLESDALE.

of *Trochoceras giganteum* Sow., though I have procured it from a higher horizon near Dent. Considering the enormous extent of bedding face exposed, fossils cannot be regarded as common, yet some can generally be obtained, but the locality is not nearly so rich as the quarries at Dry Rigg on the same horizon further south in the upturn of the synclinal.

About 300 yards further south, we come to Combs Quarry, Fig. 5, which is very much higher in the series. The flags have here also been worked right up to the precipice so that we have the Silurian and the overlying Mountain Limestone seen in one vertical section about 100 feet in height. The dip is about 40° to 45° to the south, and the inconspicuous cleavage transverse to it at a very high angle. Strong master joints traverse the rock and, dividing it into large blocks, greatly facilitate the work of quarrying.

Dry Rigg runs out in a kind of promontory forming the southern boundary of the ancient tarn, now converted into a peat moss, which forms such a conspicuous feature at the foot of the upper flat valley of Horton. This, with its rapids below, corresponds as a geographical feature with Chapel-le-dale and Kingsdale and their gorges running down to Ingleton. For this reason it seems probable that these surface features are largely due to the conditions prevailing during the recession of the ice rather than to the different character of the rocks traversed, and therefore the explanation will be discussed under the head of glacial phenomena rather than as illustrating the varieties of rock in the line of our section. Along this ridge many quarries have been opened, and here the greatest number of specimens has been obtained from the Horton Flags, amongst which were all those mentioned on p. 67, except *Trochoceras giganteum.* The fossils, especially the corals, commonly occur here in calcareous concretions. The rest of the section calls for no special remark. The Austwick Flags and Grit rise in the crushed and faulted southern limb of the synclinal fold, and strike in an easterly direction along the great strath that runs to Austwick, but as I have already pointed out (vol. xiv., pp. 144, 145, Figs. 4, 5) these beds were probably reduced to much their present surface level by denudation in pre-Carboniferous times.

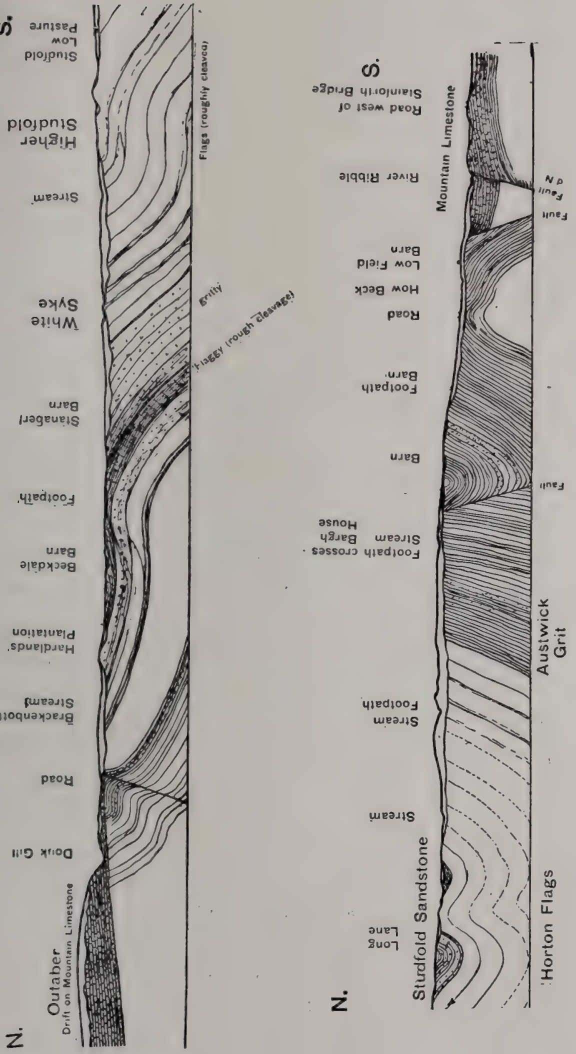

Fig. 8.

SECTION ALONG EAST SIDE OF RIBBLESDALE.

The section along the east side of Ribblesdale (Fig. 8) is much obscured by moraines and alluvium. I have, however, filled it in by inference from the strike of the beds, and the direction of the faults in the closely adjoining area, and have carried it further to the north and to the south than was necessary for my present purpose, as such suggestions may save the time of those who in the future may work out more fully the geological history of this most interesting valley. It will be convenient to start from some easily found point, and I will suppose that we are looking north from Stainforth Bridge ; Great Stainforth is on the right ; and Little Stainforth on the left ; Dog Hill Brow runs along what is the left bank of the river ; while, further on, Little Wood follows the right bank. The rocks are Carboniferous, lying horizontally. Crushed rock and conflicting dips indicate a small broken fold or fault, with a downthrow on the north, near the north end of Dog Hill Brow. The section here passes to the other side of the river south of Low Field Barn, and crosses the line of fault, which throws the Mountain Limestone down on the south against Silurian rocks which appear to belong to the Austwick Grits and Flags, and these near Bargh House pass under the Horton Flags, which are quarried about a quarter of a mile east of Bargh Hill. The flags in turn pass under A, b, 4, the Studfold Sandstone, which is well seen at several places in Long Lane, especially near the guide post where Long Lane joins Moor Head Lane. The flags turn up again about the south end of Studfold Lane pasture, and are quarried at Studfold. The Austwick Grits and Flags succeed in descending order to the north, and near Stanaber Barn alternations of flags and roughly cleaved sandy mudstone and sandstone belonging to this series are seen in ice-worn bosses here and there. Flags, probably in the lower part of the series, are exposed along the road north-west of Dove Cote, and extend in gentle undulations west of Beckdale Barn and north-west of Redding Barn. Flags are quarried in Hardlands Plantation, north of which, and to the south-west as far as Hardlands Barn, there is a tough sandstone, which appears to come out from under the flags in the Plantation. Beyond this the section is much obscured by drift and alluvium, but before we reach Douk Gill we see the Mountain Limestone creeping south over Bala Beds, and we might expect to find the base of the Silurian if we could remove the superficial deposits.

The Horton Flags are seen in these three sections to lie in a synclinal trough, the axis of which slopes gently to the east, so that we see only a little of the flags in Crummack Dale, more along the west flank of Ribblesdale, and the whole, up to the base of the overlying Studfold Sandstone, along the east flank.

The Horton Flags are the equivalent of the Upper Coniston Flags of the Lake District and of the Nantglyn Flags of North Wales.

As happens in so many cases, the fact of their being of commercial value helps to give them a geological importance, because they are rendered accessible in quarries, fresh surfaces are exposed for investigation, and the workmen preserve fossils for the collector. In this case it would have been especially difficult to procure fossils on the weathered outcrops. They are not often abundant even when we have thousands of feet of freshly split flags in which to search for them.

In the great quarry at Arco Wood I found *Trochoceras giganteum* Sow. in situ; *Actinocrinus pulcher* Salt., etc., but the best locality for fossils is in the quarries along Dry Rigg a little further south, where they very commonly occur in calcareous concretions, and from which all the following fossils, except the *Trochoceras*, have been procured :—

Orthoceras primœvum Forbes.
O. Sedgwicki Forbes (? = *O. tenuicinctum* Portl.).
O. sp.
Meristella tumida Dalm.?
Cardiola interrupta Brod.
Pterinœa tenuistriata McCoy.
Actinocrinus pulcher Salt.
Favosites fibrosus Goldf.
F. sp. small form akin to *F. gothlandica.*
Trochoceras giganteum Sow.
Monograptus colonus Barr.
M. bohemicus Barr.
M. rœmeri Barr.?

Our list, therefore, represents only one horizon near the base of the 2,000 feet of Horton Flags, but it is probable that zones characterised by a different facies may be made out in such a thickness even of fairly uniform sediment. A beginning might be made by comparing the fossils of Arco Wood with those of Combes Quarry, which is much higher in the series.

ORTHOCERAS.

The *Orthoceras primævum* is the fossil described under the name *Creseis primæva* by Ed. Forbes[*] who, in both cases, refers to the longitudinal grooves so commonly observed in the flattened specimens. McCoy,[†] however, in 1855, pointed out that the longitudinal groove was only a crush in the last chamber, and Salter,[‡] in 1873, described it as "easily crushed." The tendency to break in this manner is obviously a characteristic of the species.

The other common *Orthoceras* is evidently that described by Forbes[||] as *Creseis Sedgwickii*, which was considered by Salter[§] to be the same as *Orthoceras tenuicinctum* of Portlock.

THE STUDFOLD SANDSTONE.

The anticlinal axis referred to above in describing the surface extension of the Horton Flags still falls to the east, so that on the east side of Ribblesdale the centre of the fold is still further depressed and the northern and southern base of the series are nearly two miles apart. In the centre of this anticlinal, which has here a double fold, the next overlying series, namely, the Studfold Sandstone, comes on above the Horton Flags just as the Horton Flags themselves crept out in a synclinal fold over the Austwick Grits in Crummack Dale. We have thus the whole thickness of the Horton Flags represented in Ribblesdale.

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[*] Q.J.G.S., vol. i., (1844), p. 146, fig. 1, and vol. ii., p. 314, Pl. XIII, fig. 2.

[†] Synopsis, &c., Sedgwick and McCoy, p. 316.

[‡] Salter Catalogue, Camb. Sil. Foss., p. 159.

[||] Op. cit., p. 146.

[§] Op. cit., p. 158.

Taking a traverse from the footpath about half-way between Beckdale Barn and Stanaber Barn we infer from the adjoining area the occurrence of the Austwick Flags and Grits with a northerly dip which brings on the Horton Flags in due succession about 100 yards south of White Syke. The beds become nearly horizontal under Higher Studfold, but plunge down again to the north under Studfold Low Pasture and, as might be expected from such a long continuance of northerly dips, we now arrive at the top of the series, and the overlying Studfold Sandstone comes on in a synclinal fold. Soon after we pass Long Lane a pretty sharp anticlinal brings the flags up again, but not for more than 200 yards, when the Studfold Sandstone is once more caught in a small synclinal. East of the line of section (p. 65) the rise of the ground gives such a thickness of this sandstone that the Horton Flags are not brought to the surface in the anticlinal fold mentioned above, but the Mountain Limestone rests on the Studfold Sandstone for about half a mile. From this point onwards the section is much obscured by drift, and the moraine mounds cover almost all the ground, and more and more of the succession has to be inferred from the adjoining area.

If we cross the spur of Mountain Limestone and examine the Silurian rocks exposed in Silverdale we shall find the Studfold Sandstone coming out just where we should expect it if it was prolonged to the east with the normal strike under the Carboniferous rocks. Some of the higher beds are, as in the corresponding part of the series in other areas, much coarser than anything seen along the east flank of Ribblesdale, and it is in this coarser part that I think we have the nearest representative of the Winder Grits. It would be interesting to find here the same group of fossils of Ludlow facies which is so marked in the Winder Grit at Sedbergh. I have never been able to examine this area properly, but here I think we might find, in the finer beds above the grits, the zone of *Acidaspis hughesii* Salter. The nearest point where I have found it is about eight miles on the north-west of Ingleborough (Geol. Mag., vol. iii., May, 1866, p. 206), and it would be a very helpful bit of evidence for the correlation of these most easterly Silurian beds if we could establish its occurrence here. The *Ceratiocaris* described by Dr. Woodward, ib., p. 205, should also be found at the same horizon.

CARDIOLA INTERRUPTA BROD.

This species is, I believe, so far as at present known, absolutely confined to the Silurian rocks, and therefore most useful when we are trying to separate them from the Bala Beds which they often much resemble in lithological character.

I have hammered out *Cardiola interrupta* in the Sedbergh district, in Hebblethwaite Gill for instance within a few inches of the base; I have found it also in the highest beds of the Ludlow Rocks, and it occurs here and there throughout the intermediate beds.

Barrande states that it occurs in the Bala Series, but that is due to a mistaken identification ot strata. When I commenced to map the Silurian rocks of the north of England the Coniston Grit was called Caradoc Sandstone, and as *Cardiola interrupta* was the most marked fossil of the Coniston Grit, it got into Etheridge's list of Caradoc fossils. On that authority Barrande put it down as a Caradoc form. As the result of my mapping and fossil collecting I inferred that the Coniston Grits and Flags, in fact, everything down to the Austwick Conglomerate, was Silurian, i.e., Upper Silurian of the Survey, so that there was, as yet, no authority for putting *Cardiola interrupta* into the list of Caradoc or Bala fossils.* Owing to circumstances over which I had no control I was not then able to follow the matter up.

It may be useful here to call attention to the progress of identification and subdivision of the Silurian rocks of this district and the changes and limitations of nomenclature which accompanied them.

Before the six-inch ordnance map was published, and in some cases before there was even a one-inch map to be obtained, it was difficult to fix and trace boundaries, estimate thicknesses, and define exactly the groups of strata referred to. It may be that these and other difficulties in the way of working out details made the pioneers of geology concentrate their thoughts on those large stratigraphical generalisations which strike us so much in their work.

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* Geol. Mag., vol. iv., No. 8, Aug., 1867, p. 11.

In the case of the rocks we are now considering there were great masses of more or less sandy mudstone and shale, often under local conditions becoming flaggy and generally having a good deal of subordinate sandstone or grit intercalated among the lower beds, and similar coarse material making up nearly the whole of the upper part of the series. These were the Denbigh Grits and Flags of North Wales, and the Coniston Flags and Grits of our district.

There were also on a lower horizon in the Bala Beds, great masses of sandy mudstone, sometimes becoming flaggy.

In the Builth district in South Wales also, there were an upper series of flags belonging to the Wenlock, and a lower series known as the Llandeilo Flags. These were at first confounded together, but were afterwards separated and found to be characterised by an entirely different group of fossils. The identification of these several series in different areas was a question for palæontology, but until the succession had been clearly ascertained in some one area by stratigraphy, the palæontological evidence might be, and indeed was, misleading, as we find from the history of one of our most important fossils, *Cardiola interrupta.*

Salter, who was as good in the field as he was in the museum, maintained that there were in Wales two sets of flaggy mudstones, an upper belonging to the Silurian, and a lower to the Bala Series. This was in time clearly made out in the Lake District, in North Wales, and in the Builth area in South Wales. The Coniston Flags at first included everything down to the bottom of the Austwick beds. The examination had not yet been so close and detailed as to detect the thin interrupted beds of conglomerate at the base, nor the Graptolitic Mudstones, nor the Austwick Flags or Grits, as subdivisions which might be locally separated and often identified in widely separated areas. We have, therefore, to be careful to avoid the confusion that might arise from our sometimes quoting the earlier writers who used the term Coniston Flags for the whole, and another time referring to authors who speak of the "Coniston Flags proper" or the Upper Middle and Lower Coniston Flags, while they intend to exclude the lowest beds.

The following references and extracts will enable anyone to verify the history of the clearing up of this part of our Silurian classification.*

Harkness and Nicholson evidently were collecting from the Coniston Flags when (Quart. Journ. Geol. Soc., vol. xxiv., 1868, p. 480) they recorded the fossils *Cardiola interrupta*, *Actinocrinus pulcher*, and (ib. vol. xxiv., 1868, p. 298) the Graptolites *G. priodon*, and *G. sagittarius*, but they had not yet got the key to the classification, for they state that "two important members of the Silurian Series are wanting in the Lake Country, namely, the Llandovery rocks, and the Wenlock Group. In this district we have no smooth *Pentameri*: *Atrypa hemisphœrica*, *Encrinurus punctatus*, and other Upper Llandovery fossils are absent; nor do the characteristic fossils of the Wenlock occur." The same authors, however, soon made a great advance towards clearing up the difficulty by their discovery of "the occurrence in the Lake District of a new and unique horizon containing a rich graptolite fauna in that portion of the Silurian Series which had been termed by Professor Sedgwick "the Coniston Flags."

"The succeeding and conformable mudstones introduce an entirely new fauna, and one which has no representative in Great Britain among the rocks appertaining to the Caradoc age" (op. cit., p. 301). They do not, however place them above the Caradoc, but below it. "The species from these mudstones (with the exception of three, *G. Sedgwickii*, *G. priodon*, and *G. tenuis*) and the new forms are also equally confined in Great Britain to the Upper Llandeilo rocks and another form, *Rastrites peregrinus*, also has hitherto been found in Britain only in the same horizon."

It is obvious that the fossils had been collected from flags of different age. The Upper or Silurian Flags of Builth had not yet been separated from the lower or Bala Beds of similar appearance, and they had not yet distinguished their Graptolitic Mudstone into which the Coniston Flags pass down, from the Ashgill or Fairy Gill Shales, into which the Coniston Limestone passes up, and Sedgwick's "separation of the so-called Caradoc Sandstone into two distinct groups, viz., (1) May Hill Sandstone; (2) Caradoc Sandstone," proposed to the Geological Society in 1852* had not yet been accepted.

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* cf. Siluria, 3rd Ed., p. 127.

Harkness and Nicholson therefore thought that the result of their researches was "to add a great thickness of strata to the highest member of the Lower Silurian rocks."

Murchison was, of course, not unwilling to accept this view, and when the members of the Geological Survey commenced work in the north of England the Coniston Grits were officially considered to be the equivalent of the Caradoc Sandstone.

Now it was stated as part of the evidence for the Llandeilo or at all events Lower Silurian age of the Graptolitic Mudstones, that among the strata which were associated with the Graptolitic Shales in Ireland, *Cardiola interrupta* was met with, ib., p. 302, and it was a common fossil in the Coniston Flags and Grits which were held to be of Caradoc age, and therefore *Cardiola interrupta* was a lower Silurian and even Llandeilo fossil.

Mr. Etheridge, palæontologist to the Survey, entered it as such in his lists.

On this authority Barrande accepted *Cardiola interrupta* as a Lower Silurian Form.

DÉFENSE DES COLONIES V.

Apparition et réapparition en Angleterre et en Ecosse des espèces coloniales Siluriennes de la Bohême, d'après les documents Anglais les plus authentiques et les plus récents. 1881.

"Anjourd'hui, l'extension verticale de *Cardiola interrupta*, dans les régions typiques siluriennes, est constatée par des documents, que nons exposons *in extenso* dans notre vol vi., *Acéphalés*, p. 46., in 4to et. dans notre Extrait in 8vo, p. 72, qui vont être publiés.

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* Q.J.G.S., vol. ix., 1853.

D'apres ces documents, *Card. interrupta* existe non seulement dans Caradoc ou Bala, dans la région typique d' Angleterre, suivant les anciennes indications de la *Siluria*, mais elle a été découverte sur un horizon inférieur, dans l'étage de Llandeilo. Ce fait, longtemps inconnu, repose sur le témoignage de M. le Président R. Etheridge, qui l'a constaté dans son *Discours anniversaire* du 18 Février, 1881 (Quart. Journ., vol. xxxvii., Part 2, p. 117, No. 146, May).

Ainsi, notre assertion au sujet de *Card. interrupta* est non seulement confirmée, mais elle est encore étendue verticalement au dessous des limites que nons avons supposées en 1870."

But now the Builth Flags have been divided into a Lower Bala Series and an Upper Wenlock Series ; now the Caradoc Sandstone of Murchison has been shown to be made up of a lower division belonging to the Bala, and an upper division belonging to the Silurian ; and now the Coniston Flags and Grits have been proved to be Silurian ; and *Cardiola interrupta* has been found in the Upper Series only in each case.

A NOTE ON THE CARBONIFEROUS SEQUENCE IN THE NEIGHBOURHOOD OF PATELEY BRIDGE.

BY ARTHUR VAUGHAN, B.A., D.Sc., F.G.S.

INTRODUCTION.

During the visit of the Yorkshire Geological Society to Pateley Bridge, in April of the present year (1906), I had the welcome opportunity of examining the Carboniferous Sequence in that district. Although the material which I then obtained has not yet been completely examined, I deem it good policy to set forth, here and now, a general summary of the facts which the visit has established, as well as of the facts upon which further light is required, in the hope that more much-needed material may be forthcoming. I therefore appeal to the numerous and keen workers of the Yorkshire Geological Society to undertake the elucidation of those more difficult problems which can only be solved by continuous and exhaustive field work. A flying visit to a new district raises an easy crop of suggestions, but the credit of final truth can only be gained by the worker who has examined every exposure throughout the area.

THE CARBONIFEROUS SEQUENCE.

I.—THE D_2 LIMESTONE.

The lowest horizon which was examined, in the immediate neighbourhood of Pateley Bridge, consists of massive fossiliferous limestones. These beds are excellently exposed in the quarries on Greenhow Hill, and contain a rich fauna of Corals and Brachiopods.

The horizon of these limestones is unquestionable; the included fauna indicates with certainty the upper part of the *Dibunophyllum*-Zone (D_2) of the Avonian Sequence.

The following fossils (selected from a much longer list) are of common occurrence in the Greenhow Quarries, and constitute an assemblage, which, in the South Western Province, is absolutely distinctive of D_2. In fact, the fauna is practically identical with that of the Rownham Hill Quarry, in the typical sequence of the Avon Gorge (Bristol).

CORALS.—Clisiophyllids :
Lonsdaleia, *Dibunophyllum* (of advanced structural type, cf. *Dib.* ψ), *Acrophyllum*, *Cyclophyllum*.
Lithostrotions :
Siphonodendron irregulare and *S. junceum*.
Nematophyllum Portlocki and *N. M'Coyanum*.

BRACHIOPODS :—
Spirifer planicosta and *S. bisulcatus*.
Productus '*giganteus*,' *P. antiquatus*, and *P. longispinus*.
Reticularia imbricata and '*R.*' *lineata*.

DIGRESSION.

For the benefit of those who are unacquainted with the results of recent work upon the Carboniferous Sequence, the following broad outline is inserted.

The Avonian of the South Western Province is divided into two great divisions.

With the lower of these two divisions we are entirely unconcerned; it is certainly unexposed in the Pateley Bridge area and, if a boring were made (say at Greenhow Hill) through the underlying Carboniferous Rocks, this division would most probably be found to be entirely absent (v.i.).

The Upper Division (or Kidwellian) may be very approximately defined as the range of *Lithostrotion*. It is sub-divided into two zones, namely, the *Seminula*-Zone below, and the *Dibunophyllum*-Zone above.

If such a boring as has been conceived above were carried out, it would most probably pass through part at least of the *Seminula*-Zone, before striking rocks of much greater antiquity. Be this as it may, the limestones which are actually exposed at the surface, in the immediate neighbourhood of Pateley Bridge, belong to the *Dibunophyllum*-Zone and, in so far only as the exposures which I visited are concerned, to the upper part of that zone (D_2 or the sub-zone of *Lonsdaleia*).

The *Dibunophyllum*-Zone is approximately equivalent to the range of *Dibunophyllum*, the typical genus of the Clisiophyllidan Corals. (The Clisiophyllidan plan of structure, indeed, affected the gentes of cognate families, as well as the group of which it is the essential property, and this fashion may be regarded as a time-trait distinctive of the *Dibunophyllum*-Zone.)

The *Dibunophyllum*-Zone roughly coincides also with the range of *Productus* '*giganteus*,' for, in the South-Western Province, *P.* '*giganteus*' comes in at the top of the *Seminula*-Zone, ranges to the top of D_2, and becomes practically extinct in D_3.

There is, indeed, a striking parallelism between the Clisiophyllidan Corals and that group of *Producti* which is loosely labelled *P.* '*giganteus*.' Both are examples of the structural aggrandisement which precedes extinction. In *Productus* '*giganteus*,' the great size and mass of the shell, the irregularity of the ribbing (here confluent and flexuous, there forked and knotted) and the irregularly dispersed spines constitute a lavish excess of ornament which, almost invariably, heralds extinction. In the Clisiophyllids, the extraordinary complexity of the central area and the irregular vesicular structure of the periphery are highly specialised characters, the acquisition of which necessarily involves loss of plasticity in the gens.

Hence it is quite correct, both theoretically and practically, to select *Productus* '*giganteus*' as a zonal index, and this is the method adopted by the Belgian geologists.*

The main objection to this course is that it is extremely difficult to detect the underlying progressive variation in the case of a group so irresponsible and protean as that of *Productus* '*giganteus*.' (It seems to be the fact, however, at least in the South-Western Province, that forms of *P.* '*giganteus*' which converge towards *P. latissimus* distinguish D_2 rather than D_1 and, in the North England Province, Professor E. J. Garwood has pointed out that *P. latissimus* marks a definite level throughout the area.)

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* In the "Légende de la Carte Géologique de la Belgique" (1900), the upper Viséan (V_2) is stated to be characterised by *Productus Cora* and *P. giganteus*.

On the other hand, in the case of the Clisiophyllids, structural variation can be studied with ease, and the increase of complexity, as we progress through the *Dibunophyllum*-Zone, is convincingly exhibited; for example:—

Dibunophylla, of the θ stage in D_1, reach the ψ stage in D_2.

Konickophylla in D_1, become *Acrophylla* in D_2.

Clisiophylloid *Lithostrotion* in D_1 leads on to *Lonsdaleia* in D_2.

In fact, the employment of the Clisiophyllids, rather than *P.* '*giganteus*,' is comparable with the use of a delicate balance, in place of a clumsy pair of scales.

OTHER EXPOSURES OF D_2 LIMESTONE.

Two other exposures of the massive limestone were hurriedly examined, both situated on the right bank of the Nidd.

In the first, at Lolley Scar Quarry, the limestone underlies the fossiliferous black shales which are again referred to below. The fauna of the limestone appears to agree with that of the shales, but very few Brachiopods were observed, and no Corals.

In the second, near Limley, *Petalaxis Portlocki*, *Campophyllum derbiense*, and a Dibunophyllid, identical with a form which occurs at Greenhow, seem to fix the horizon of the beds as approximately on the same level as the Greenhow Quarries, that is, in D_2.

The stratigraphical correlation of the several limestone exposures can only be arrived at by detailed field work, and more material is necessary to complete the faunal survey. It is also probable that careful search will bring to light lower horizons than any which were examined during the Easter excursion.

II.—THE SHALES BETWEEN THE MASSIVE LIMESTONE AND THE 'MILLSTONE GRIT.'

Black fossiliferous shales were examined at two points:—

(1) In Lolley Scar Quarry, where they rested immediately upon the top of a massive limestone (v.s.).

Here the fauna of the shales includes the following forms :—

Spirifer bisulcatus (long-winged form), abundant.
Productus longispinus (especially the variant, *P. longispino-concinnus*), abundant.
P. antiquatus.
P. corrugatus (with Orthotetoid convergence).
Orthotetes (with strongly-marked periodicity of ribbing).
Camarophoria sp.

No corals were found.

This list affords clear evidence of the D_2 sub-zone, but does not do more than *suggest* a particular level within that sub-zone.

The occurrence of *P. longispino-concinnus*, of a variant of *Spirifer bisulcatus* with extremely elongated wings, and of a variant of *P. corrugatus* with a very specialised type of ribbing, suggests a time posterior to that at which the normal forms of these species flourished, and therefore a high level in D_2. The evidence is, however, inconclusive, in that deviation from the normal may be a consequence of variation in conditions, rather than of evolution in time.

In the South-Western Province, similar forms occur at the very top of D_2 in a similar lithological environment, but, since we have no knowledge of the fauna which accompanies the same conditions during the main D_2 period, we are unable as yet to make a more definite assertion as to horizon.

(2) At the Angram Water Works Section, the black shales pass upward without apparent break into the 'Millstone Grit,' and the fact that the complete establishment of 'Grit' conditions is preceded by siliceous bands in the upper portion of the shales strengthens the evidence for continuity of sequence.

In so far as I was able to judge from an extremely incomplete examination of the section, the fauna of the shales at Angram differs from that of the shales at Lolley Scar Quarry in several important respects.

Brachiopods are not in great abundance; *Spirifer bisulcatus* is apparently uncommon, and *Productus longispinus* was not recorded. *Martinia glabra* is, however, common at certain levels and, in its characters, presents a strong resemblance to the form of this species which is abundant, in the uppermost beds of the Avonian, in the Gower Peninsula. Corals are rare, with the exception of *Pseudamplexus nodulosus*, a species in which extreme simplicity of structural plan is combined with a knobbed, wrinkled, and twisted outward form—characters which indicate extreme decadence. This form is known only from D_3 (the *Cyathaxonia*-Beds), at which level it is of very general occurrence.

Specimens of *Posidonomya membranacea* were also collected from the shales, and this shell is recognised by Dr. Wheelton Hind as a characteristic Lower Pendleside form.

It seems, then, that we are justified, at least as a working theory, in assigning the Angram Shales to D_3 and Lower Pendleside; but more material and a more careful examination of the section, bed by bed, is absolutely necessary before the conclusions here suggested can be considered to be placed beyond dispute. The exhaustive description of the Angram section is a duty which Yorkshire geologists would be wrong in shirking, and which, I feel sure, will be embraced by them with avidity and carried to a successful issue with characteristic thoroughness.

It is necessary, at this point, to consider what is known concerning the relation of the Pendleside Series to the uppermost portion of the Avonian.

Sections showing a continuous sequence from Avonian up into Pendleside are unfortunately extremely rare,* and, in the majority of exposures, it is only possible to assert that limestones containing a D_2 or D_3 fauna are *succeeded* by shales containing *Posidonomya Becheri*.

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*Dr. C. A. Matley has just completed the stratigraphical examination of the coast section from Rush to Skerries, in the County of Dublin. Here, there is an unbroken sequence from Cyathaxonia Beds through the *Posidonomya Becheri* Beds. He has carefully and exhaustively collected from each bed, and has sent the material to me for examination. We may consequently hope to finally settle the inter-relation of these two sets of beds at no very distant date.

Dr. Wheelton Hind cites a conformable sequence from Avonian into Pendleside at Grange Quarry, near Holloway (Geol. Mag. (1906), p. 450), but the beds apparently do not yield a large fauna.

(1) D_3 (UPPERMOST AVONIAN).

A typical D_3 fauna may be classified as follows:—

Specialised, decadent, and reverted forms:

Productus longispinus.

Zaphrentis aff. *Enniskilleni* and *Zaphrenti-Amplexus.*

Pseudamplexus, *Beaumontia*, cf. *Favosites.*

Peculiar forms:

Cyathaxonia rushiana, *Cladochonus* and *Beaumontia.*

Abundant forms:

Martinia glabra, *Spirifer bisulcatus*, *Productus corrugatus*, and Orthids (all of which usually exhibit moribund characters).

Clisiophyllids and *Productus* '*giganteus*' are rare.

It is well known that this fauna does actually characterise the highest beds of the Avonian in several areas, but, since the lithological character of the beds in which this fauna occurs is always a peculiar one, it is not, as yet, certain to what extent the D_3 fossil-assemblage is a function of its environment. In other words, we do not know that the same environment, during D_2 time, was not characterised by a very similar fauna. It seems most probable indeed that time-variation has been, at least, exaggerated by the variation consequent on change of environment.

(2) THE POSIDONOMYA BECHERI BEDS (LOWER PENDLESIDE).

The shales which are crowded with *Posidonomya Becheri* unquestionably indicate very definite conditions of depth and deposit; it follows, therefore, that the sudden appearance of *Posidonomya Becheri* merely indicates a change of conditions, and by no means implies that the Pendleside fauna is the lineal descendant of the D_2 or D_3 faunas.

It is, as yet, unknown to me at what time *P. Becheri* made its first entrance, for I know of no deposits, during D_2 time, which indicate an environment or bathymetric level identical with that of the *P. Becheri* Beds. It seems, however, probable that the *Cyathaxonia* and *P. Becheri* faunas were, at least in part, contemporaneous, though each was undoubtedly the expression of a distinct bathymetric level. At the same time, the evidence points strongly to the conclusion that the *P. Becheri* Beds are, in the main, later than, and successive to, the *Cyathaxonia* Beds.

In my opinion, Dr. Hind has rendered an immense service to Carboniferous stratigraphy in insisting upon the distinctness of the Pendleside fauna, and he has fully appreciated the earliest possible level at which it is imperative to forsake the corals and Brachiopods and to rely upon Lamellibranchs and Goniatites.

III.—THE 'MILLSTONE GRIT' OF PATELEY BRIDGE.

Assuming that the base of the 'Millstone Grit' is conformable to the Angram Shales, it follows that the introduction of 'Grit' conditions took place in early Pendleside time and that the lower part of the 'Millstone Grit,' in the Pateley Bridge area, corresponds to the Pendleside Shales of N. Stafford. This conclusion places the date of the introduction of the 'Millstone Grit' period in the Pateley Bridge area appreciably later than in the Bristol area, where D_3 is very abbreviated, and the 'Millstone Grit' succeeded D_2 limestone almost immediately.

With the fauna of the 'Millstone Grit' I have little concern, except the interest which attaches to the Brachiopods which survived from Avonian times.

In some fossiliferous beds, which we visited in the 'Millstone Grit' of the immediate neighbourhood of Pateley Bridge, the following Brachiopods occurred in considerable abundance:—

Orthotetes sp.
Derbya sp. nov.
Schizophoria resupinata.
Productus concinnus (spinose mutation).
P. corrugatus.
Chonetes sp.
Spiriferina cf. *cristata.*

The *Derbya* is remarkable for its size and for the striking development of the mesial septum of the pedicle valve.

SUMMARY AND THANKS.

I am painfully conscious that this note, lengthy as it has no right to be, sets forth few fresh facts; but should it induce one Yorkshire geologist to examine with minute care the faunal sequence in the Angram Section, it will, in my opinion, have amply justified its publication.

To Dr. Hind, the President of the excursion, I am under perennial obligation, and to the Rev. W. Lower Carter I am indebted for a welcome and kindness which has no equivalent in desert. My thanks are also heartily rendered to the members of the Yorkshire Geological Society, who devoted so keen an attention to a subject which must seem petty when compared with the brilliant research initiated by Professor Kendall. To him I am much indebted for many specimens which have materially strengthened the conclusions set forth in this paper.

To Mr. Cosmo Johns, I offer my congratulations on the important and successful work which he is carrying out so carefully in the Ingleborough and Yoredale Area, and it is upon the general trend of his work that I have based some of the speculations in this note.

ON A CARBONIFEROUS TRILOBITE FROM ANGRAM, IN NIDDERDALE.

BY HENRY WOODWARD, LL.D., F.R.S., ETC.

Dr. F. A. Bather recently transmitted to me some remains of a small Trilobite from Angram, in Nidderdale, which he had received from Mr. E. Hawkesworth, of Leeds. The fossils are contained in black carbonaceous shales occurring below the Millstone Grit in the *Cyathaxonia* beds immediately below the Lower Culm, and on the same horizon as those at Bishopston, Glamorganshire, which yielded to Mr. F. Barke, F.G.S., a good example of a new species of Trilobite named *Griffithides Barkei* (see my paper on "Culm Trilobites", Geol. Mag., 1902, pp. 484-486, Pl. XX., Figs. 14, 15). The Nidderdale black shales contain numerous detached portions of a small Trilobite, a *Pecten*, and several Brachiopods.

The fossil was found during the field excursion of the Yorkshire Geological Society to Nidderdale, under the leadership of Dr. Wheelton Hind and Dr. Arthur Vaughan, on Friday, April 13th, 1906.

One nearly perfect example of this Trilobite from Angram measures 17 mm. long by 10 mm. in breadth. At first sight I took it to be *Phillipsia Eichwaldi*, but the glabella is more tumid and triangular in form, and the front border projects beyond the margin of the head-shield, whilst it contracts posteriorly to a point at its cervical border, as seen in all typical forms of the genus *Griffithides*.

The cheek-spines are long, and extend to the sixth thoracic segment. The compound eyes are large, and placed laterally, and well behind the projecting and expanded front of the glabella.

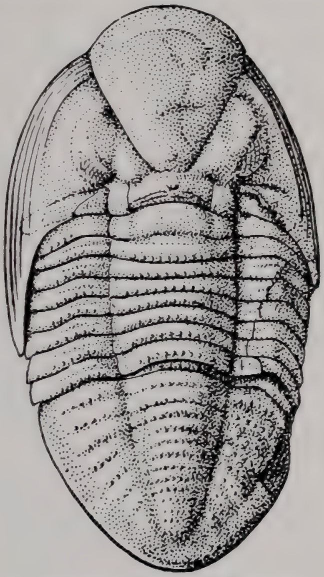
The posterior point of the glabella is prominent and marked by a tubercle (the surface, however, is partially decorticated and only the prominence is shown on the cast). There is a small triangular rounded glabellal lobe on each side behind the compound eyes, and close to the posterior (cervical) border of the head-shield.

The neck-lobe is prominent, and from the evidence of a detached head, we know that there was a central spine or tubercle on its axis.

The axis of each of the nine free thoracic segments (only eight of which can be seen on one (the left) side, owing to an overlap) is fringed by very minute tubercles, as is also each of the fourteen coalesced somites forming the pygidium. This delicate fringe of minute tubercles also extends along the pleura on either side of the axis. The margin of the pygidium is rounded and has a smooth slightly raised border.

Measurements.—Total length of specimen, 17 mm.; greatest breadth (across cheek-spines), 10 mm.; length of head, 6 mm.; breadth, 9 mm.; length of nine free thoracic segments, 5 mm.; breadth, 8½ mm.; pygidium, length, 6 mm.; breadth, 8 mm.

Affinities.—The two species of *Griffithides* which approach most nearly to Mr. Hawkesworth's specimen are *Griffithides acanthiceps* H. W., from the Carboniferous Limestone of Craco, Grassington, Yorkshire (see H. Woodw., Mon. Brit. Carb. Trilobites, 1883-4, p. 32, Pl. VI., Figs. 2, 10, 11, and Pl. VII., Figs. 2 and 3. Pal. Soc. Vol. for 1883), and *Griffithides Barkei* (H. Woodw., Geol. Mag., 1902, pp. 484-486, Pl. XX., Figs. 14, 15), from the Culm Measures, Bishopston, Glamorganshire.



GRIFFITHIDES BARKEI H. WOODW.
Base of the Lower Culm,
Angram, in Nidderdale, Yorkshire.
× $\frac{4}{1}$ nat.
Drawn by Miss G. M. Woodward.

The former of these differs greatly in point of size, and its ornamentation is dissimilar, the head being minutely tuberculated, and the glabella less narrow behind than that of the Nidderdale Trilobite. It certainly agrees closely with *G. Barkei* from Bishopston, and according to the latest information received their geological horizon is practically the same.

The following points of difference may, however, be observed, viz., (1) The greater breadth of *G. Barkei* in proportion to its length; (2) the slightly greater length of the cheek-spines in the Nidderdale specimen; and (3) the rather broader axis to the body segments; and, again, (4) the more strongly-marked ribbing of the coalesced segments of the pygidium, which is also slightly more pointed than is the tail of *G. Barkei*; (5) the cervical segment is more strongly marked in the Yorkshire specimen; (6) the apparent greater size of the eyes in this specimen is really deceptive, and is caused by the head being rather flattened out and compressed. On the whole, however, these two forms approach very closely to each other, and, seeing they are pronounced by Dr. Wheelton Hind to occur on the same geological horizon, there is strong presumptive evidence in favour of their specific identity.

I prefer then to refer Mr. Hawkesworth's Trilobite to *Griffithides Barkei*, not feeling justified (in the present state of our knowledge) in the establishment of a new species.

THE INGLETONIAN SERIES OF WEST YORKSHIRE.

BY R. H. RASTALL, M.A., F.G.S.,

FELLOW OF CHRIST'S COLLEGE, CAMBRIDGE.

The true stratigraphical position of the group of rocks which are commonly spoken of as the "Ingleton Green Slates and Grits" has long been a matter of doubt. They have been considered by many writers to be the equivalents of the Borrowdale Volcanic Series of the Lake District, and they are coloured as "Lower Silurian" in the one-inch maps of the Geological Survey (97, S.W.). But this correlation, as was pointed out by Dr. Marr* in 1892, rests on somewhat slender foundations. It is true that the rocks possess a prevailing greenish tinge, somewhat like that of many of the Borrowdale lavas and ashes, and they certainly occur in juxtaposition with an undoubted representative of the Coniston Limestone, but the resemblance goes no further. There is nothing to show that the junction with the Coniston Limestone is a natural, conformable one, and the green rocks themselves, apart from their colour, are utterly unlike any of the members of the Borrowdale series. They are true sediments of a well-defined and peculiar type, and their constitution shows no resemblance to that of the great lava-flows, ashes, and agglomerates of the central part of the Lake District, or the thinner representatives of the same in the Cross Fell inlier. In the absence, therefore, of any direct stratigraphical evidence as to their age and relationships I propose to apply to the pre-Caradocian rocks of this district the purely local and territorial designation of the "Ingletonian Series." Some suggestions as to possible correlations will be made after their petrographical character has been described in detail, as this may be considered to throw some light on the source from which the material has been derived.

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* Geol. Mag., 1892, p. 104.

STRATIGRAPHY.

The Ingletonian rocks in the sense here defined cover a considerable area on the floor of the valley of Chapel-le-Dale, to the north of the northern branch of the Craven fault : another considerable exposure occurs in the Ribble valley, in the neighbourhood of Horton-in-Ribblesdale, and in the Geological Survey map the same series is indicated in the upper part of the Crummack valley, though the exposure here is very obscure, owing to drift and peat.

The valley of Chapel-le-Dale possesses several remarkable features : in its upper part it is wide, with a very gentle fall, but at a point about a mile above Ingleton its character utterly changes. The river plunges down suddenly into a most extraordinary series of deep gorges, with rapids and waterfalls. These gorges have obviously been formed for the most part by the coalescence of a number of gigantic pot-holes, since the peculiar outline thus produced is very clearly seen in some of the deeper pools ; this mode of origin often causes the walls of the gorge to overhang to a considerable extent, and the whole forms a scene of great beauty.

The geological structure of the Chapel-le-Dale valley above the Craven faults is exceedingly simple (see Map, Plate VII.). Its whole floor is occupied by pre-Carboniferous rocks, striking approximately N.W. and S.E., that is at right angles to the course of the stream, and dipping at very high angles, usually departing but little from the vertical ; but where the beds are inclined, they usually dip to the S.W., in a few cases only to the N.E. However, in the walls of the gorge, which are sometimes 50 feet or more in height, it can often be seen that the beds dip alternately to one side or the other of the vertical, even in this comparatively small depth, so that observations of dip on the surface are obviously of little value. Similar beds are also exposed in the lower part of Kingsdale, the valley of the Swilla, from Manor Bridge up to Thornton Force. These older rocks are overlain by practically horizontal Carboniferous Limestone. The unconformity, which is very striking, is clearly seen in many places on the sides of both valleys, and it is admirably displayed at Thornton Force in Kingsdale. On the eastern side of the Chapel-le-Dale valley there is an exposure of this unconformity which is of classic interest, since it was described as long ago as 1802 by Playfair in his "Illustrations of the Huttonian Theory."

As will be seen by reference to the map, the greater part of the area in question is occupied by an alternation of slates, flags, and grits, the Ingletonian series proper, but at the S.W. end, close to the fault, there is a narrow strip of calcareous rocks, impure limestones and shales, which are correlated with the Coniston Limestone of other districts. The rocks are much crushed and cleaved, so that fossils are difficult to extract. However, sufficient have been obtained to show that these beds are at any rate of Upper Ordovician age, probably Caradocian. The bedding is so much contorted and the junctions are so obscure that it is impossible to say whether these calcareous beds are conformable with the Ingletonian rocks or not. Lithologically they strongly resemble the corresponding strata of Edenside and the Lake District. Even at Horton, where the succession is much clearer, it is impossible to prove conformity or otherwise, owing to faulting and folding. Intruded into the Coniston Limestone of Ingleton are two or more lamprophyre dykes, which are of no great interest, as they are much decomposed. One of them is very well seen forming a barrier across the river a short distance above the fault, and close to this is another dyke of a more acid character, which may be described as a felsite.

All the rest of the area in question is occupied by a succession of slates, flags, and grits, usually of a greenish colour, and on the whole of remarkably uniform character. The total length of the exposure is over two miles, and as the dips are very high, usually approaching the vertical, the total thickness of rock exposed must be not far short of 10,000 feet, assuming that there is no repetition. It has been suggested by several authors that repetition by folding or faulting is at any rate a possibility to be considered. Professor Hughes's remarks on this point are very cautious and non-committal.* As was before pointed out, observations of dip on the surface are of little value and no folds are ever clearly seen. In the absence of any clear evidence to the contrary, the succession may be assumed to be continuous. Since the Coniston Limestone follows on in apparent, though probably deceptive, conformity at the S.W. end, and in the Ribble valley is succeeded in its turn by Silurian beds, the probability is that the sequence of the Ingletonian rocks is an ascending one from north-east to south-west.

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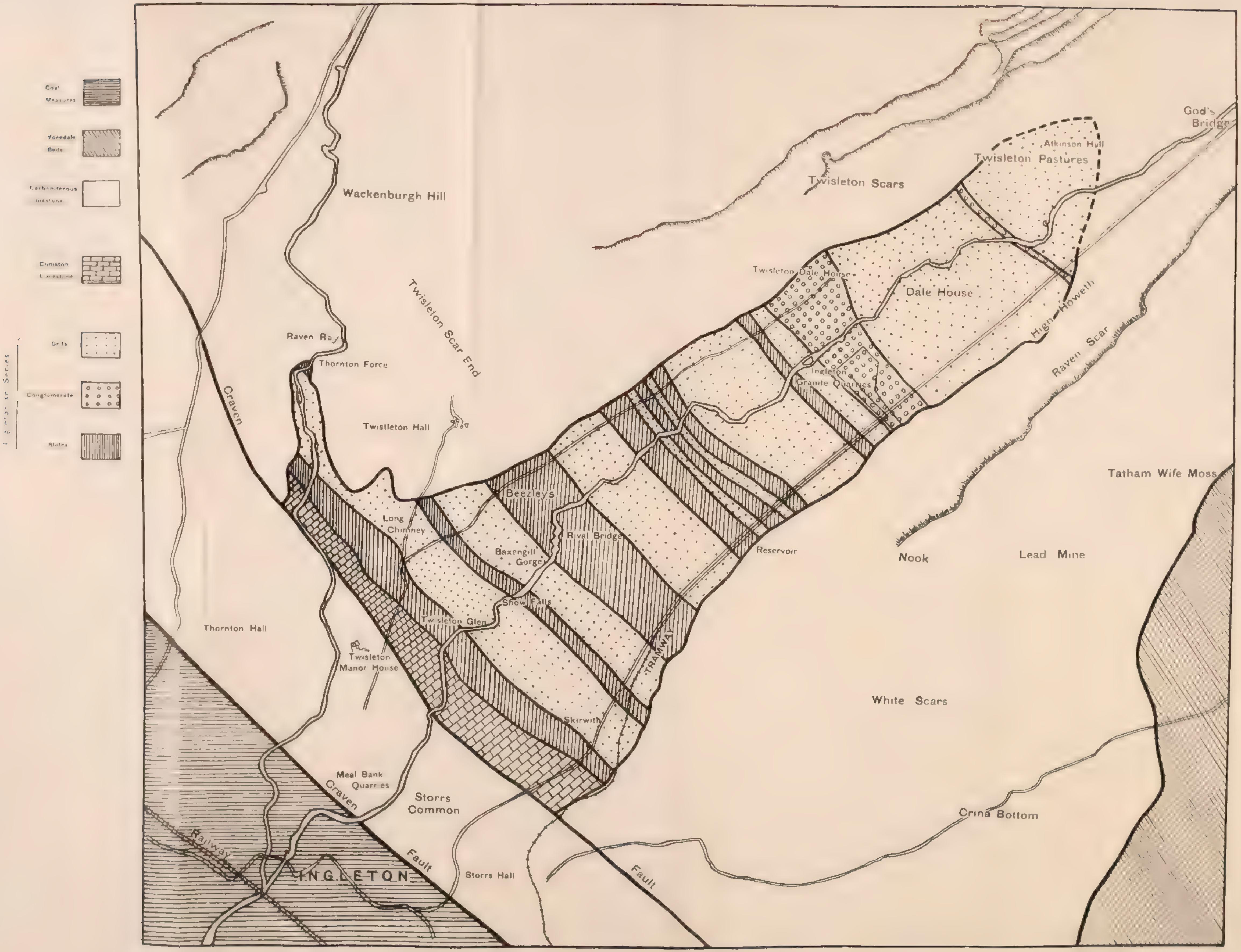
* Geol. Mag., 1867, p. 346.

Beginning, therefore, at the lowest visible bed of the series in the neighbourhood of God's Bridge, we find that the first half mile of the valley is occupied by an alternation of slates and thin bands of flags and grit, which are exposed here and there in the bed of the river, and in the fields on either side of it, especially above the Ingleton and Hawes high road. This part of the series is much obscured by drift, and very little can be said about it. Just to the south of Twisleton Dale House there comes in the thick mass of coarse conglomerate, which is now largely worked for road metal, &c., by the Ingleton Granite Company. This rock, which has a total thickness of some 800 feet, is of great interest, and will be described in detail in a subsequent section. Below this, for about two-thirds of a mile, is a rapid alternation of slates and grits, very similar to the beds seen in the upper part of the valley. Drift is also abundant here and the details are difficult to make out. From the ford at Beezley's downwards the rocks are magnificently displayed in the great series of gorges before described. Here are several thick bands of slate which were formerly worked to a considerable extent and are well-exposed in large quarries. The southernmost band is continued into Kingsdale and has been quarried on the western side of the stream close to Pecca Bridge. Another band appears at the foot of Thornton Force, and has been hollowed out into a large pool.

THE HORTON AREA.

The rocks of the Ingletonian series occupy an area of about half a square mile in the valley of the Ribble, in the neighbourhood of Horton-in-Ribblesdale. They are exposed in scattered patches, of which the most important are in the railway cutting



Proc. Yorks. Geol. Soc. Vol. XVI. Plate VII.

GEOLOGICAL MAP OF THE INGLETON DISTRICT.

immediately south of Horton Station, in the bed of the Ribble below Row End, and at Dow Gill and Town Head, east of the village of Horton. There is much drift and it is not possible to make out a continuous succession. On the whole the rocks exposed closely resemble those of Chapel-le-Dale, being chiefly grey or greenish fine-grained grits. The slate bands which presumably exist are scarcely exposed, since they have been denuded into hollows, which were subsequently filled up with drift, so that the rock-types seen are probably not representative. The grits are so similar to those of the other area as not to require separate description, but at the sharp bend of the river at Row End there occurs a peculiar conglomeratic rock, which is of some interest.

The most continuous exposure in this area is perhaps that in the railway cutting, and it is generally stated that the beds here are rather more calcareous than usual ; a band three or four feet thick occurring in one place is described in the Survey Memoir as a limestone. There is also a very good example of a crush-breccia, consisting of angular fragments of the grits embedded in crystalline calcite.

The structure and relations of the beds seen at Dow Gill, to the east of Horton, have been frequently described. Here are to be seen Ingletonian slates and grits associated with fossiliferous Coniston Limestone. The latter appears to be conformable with the Ingletonian series, but the succession is much complicated by small faults, and the true relations have not yet been ascertained. For our present purpose the only important point is that Ingletonian beds do occur in this valley, having nearly the same strike, and lying just where we should expect to find them, judging from the lie of the strata in the Chapel-le-Dale valley.

PETROGRAPHICAL CHARACTERS.

Although the lithological characters of the Ingletonian rocks have been referred to by many writers, the published descriptions appear to be based on examination of hand specimens alone, and the microscopic characters do not seem to have been investigated, with the exception of a very brief reference by

Professor Bonney.* I have therefore examined a large number of slices obtained from numerous localities, and the results appear to be of considerable interest, since the series as a whole presents certain peculiarities which may be expected to throw some light on the origin and possibly also on the age of the rocks.

As has been already mentioned, the Ingletonian rocks comprise a great thickness of massive grits and well-cleaved slates. These, however, are somewhat extreme types and many of the beds are intermediate in character, and may be regarded either as very fine grits and flags or rather coarse slates. As would naturally be expected, the effects of pressure are most apparent in the finer sediments, while the coarse grits are merely affected by systems of joint planes. Another important feature is that in many cases the beds of finer texture have been crushed between the hard masses of grits, and are often more or less contorted. Since the grits of medium texture are perhaps the most abundant and most typical, it will be well to begin our study of the petrography of the series with them.

THE GRITS.

An average specimen of such a grit is of even texture, generally of a greenish or bluish colour, and usually showing a certain amount of pink felspar and flakes of white mica. In fact, the presence of a considerable amount of detrital mica is one of the characteristics of this series.

When examined under the microscope these grits are seen to consist for the most part of angular grains of quartz and felspar, and flakes of muscovite ; there is also a fair proportion of compound grains, consisting for the most part of fragments of quartzite and other metamorphic rocks. The proportions in which the different constituents occur are very variable, but in all cases felspar and mica are present to a *notable* extent. The quartz grains vary much in size, and most of them are distinctly angular, often unusually so ; some of the larger grains are to a certain extent rounded. Much of the quartz shows distinct strain-shadows. The felspar includes several varieties, orthoclase, plagioclase, and less commonly microcline and perthite. Perhaps the most abundant is plagiolcase, and this usually shows straight extinction or nearly so, so that the dominant variety appears to be of an acid nature. Basic plagioclase is apparently absent. In all slices there are to be seen abundant flakes of mica, of all sizes ; the muscovite is fresh, as is usual in sediments, and much of the chlorite which is so common in these rocks appears to be derived from biotite. Occasionally almost unaltered crystals of this mineral can be seen. These grits often contain many crystals of heavy minerals, such as iron ores, sphene, epidote, zircon : in fact, all the minerals which commonly occur as accessories in acid igneous rocks.

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* British Association Report, 1886.

All these constituents are embedded in a cement which varies somewhat in composition, but is usually to be described as a mosaic of minute grains of quartz, enclosing tiny flakes of mica and often a certain amount of calcite. In a few specimens the proportion of calcite is so high that the rock almost deserves to be called a calcareous grit. All these rocks contain more or less green chlorite in various forms, sometimes finely disseminated through the cement, and at other times occurring in more or less idiomorphic crystals, which probably result from the decomposition of ferromagnesian minerals. The prevailing and characteristic green colour of these rocks is due to this mineral. The chlorite is undoubtedly of secondary origin, and much of it was introduced subsequently to the deposition of the rock, since the same mineral occurs very largely in the veins of both quartz and calcite which traverse the rocks in many localities (see Plate VIII.).

Different specimens of the finer grits show a good deal of variation in detail, but all may be referred to one general type, viz., a felspathic grit or arkose, with a notable amount of detrital mica, and much stained by chlorite. The angularity of the fragments is very noticeable, and suggests rapid deposition under conditions which precluded much rolling and attrition of the fragments. It is also worth mentioning that the felspar is very fresh, as much so as in the Torridonian arkoses.

THE SLATES.

The rocks described in the preceding paragraphs show comparatively few signs of crushing, but many of the finer sediments have taken on a very perfect cleavage, so that they have been extensively worked for roofing-slates. However, the quarries are now abandoned. The slates of the bands in the gorge, though not identical in appearance, are so similar that one general description will suffice for all. They are all well-cleaved slates, which split readily into thin slabs in a direction parallel to the original bedding, and other less perfect cleavages or joints divide them up into blocks of moderate size. The colour is either a bluish-grey or more commonly some shade of green, usually with a slightly olive tinge and somewhat silvery lustre. Some specimens show blackish dendritic markings on the cleavage faces. Under the microscope these slates are seen to consist of exactly the same minerals as the grits, but in a much finer state of division. Where heavy minerals occur they are often arranged in parallel layers, due to a process of sorting by current action. Here the evidence of rearrangement under pressure is more distinct, and the flakes of mica are usually seen to be bent round the grains or quartz and felspar.

The above descriptions apply to the great majority of the beds, both slates and grits, and other intermediate types, which are exposed both in the valley of Chapel-le-Dale and in the neighbourhood of Horton. But there are a few special rock-types which need separate discussion, since they are the most significant of all, though forming but a small proportion of the total mass. The most important of these are the coarse grit or conglomerate, which is worked at the Ingleton "Granite" Quarry, and the conglomerate of Row End, Horton.

THE CONGLOMERATE OF TWISLETON DALE HOUSE AND THE GRANITE QUARRY.

The manner of occurrence of this rock, which is known commercially as the "Ingleton Granite," has already been mentioned. It is well exposed in the large quarry of the Ingleton Granite Company on the eastern side of the valley. It is difficult to give any intelligible description of the macroscopic appearance of this rock, since it varies a good deal in character. The greater part of it is a coarse grit or conglomerate, consisting of crystals of quartz and felspar, both red and white, with abundant rock fragments of very variable size, and much chlorite. These constituents produce a very distinctive rock-type, having a peculiar mottled appearance and showing green, white, and red colours. There are also abundant veins of both quartz and calcite, the latter often of a pink colour. Mixed up with coarse grit there are in most parts of the mass abundant angular and subangular fragments of a fine-textured rock of a dark green colour, showing very little structure. It has been suggested that this rock is as a whole of kataklastic origin, in fact a crush-breccia, and certainly its naked-eye appearance does favour this view. But the microscopic evidence is inconsistent with this hypothesis : although the rock has undoubtedly undergone a considerable amount of crushing since its deposition, it is clearly of polygenetic origin, and the fragments are well rounded and waterworn.

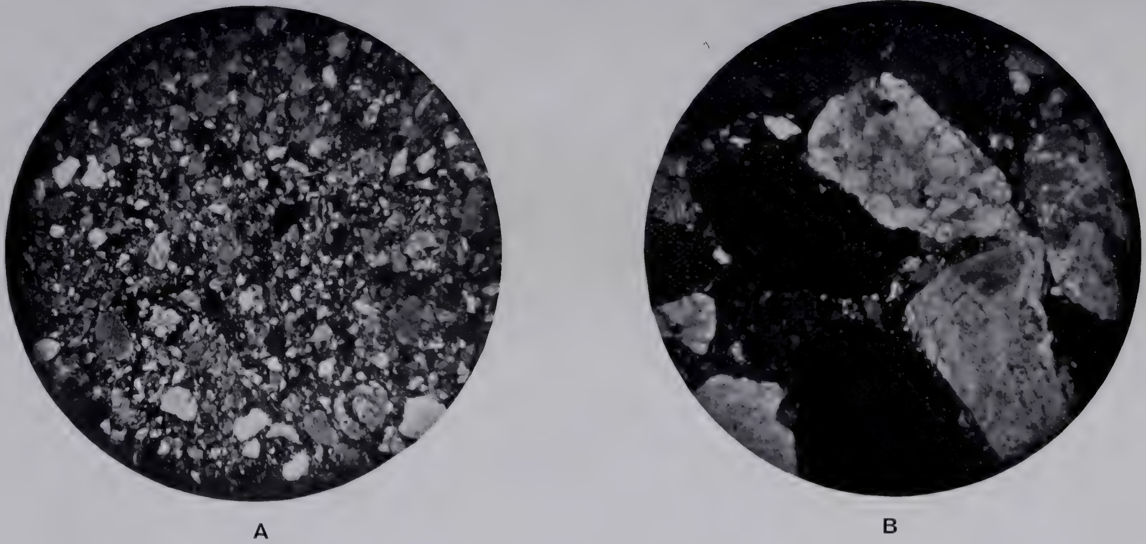
I have examined a large number of slices of this rock and the results of this examination are of interest. It consists essentially of subangular and rounded fragments of very diverse character. On the whole, the smaller fragments are the more angular, and the larger ones, which may be described as pebbles, are often very well rounded (see Plate VII.). There are abundant simple grains of quartz, felspar, and other minerals, such as have already been described in the case of the finer grits, but of more importance are the compound grains or rock-fragments, since these are usually large enough for their petrographical character to be easily recognisable. They consist almost exclusively of igneous and metamorphic rocks, and it is clear that the material of this conglomerate has been derived from the denudation of an area of gneisses and crystalline schists, together with igneous rocks of both intrusive and volcanic types.

Among the metamorphic rocks, perhaps the most conspicuous are well-rounded fragments of quartzite of various degrees of fineness, and most of them show very clearly the characteristic suture-jointing which is produced in quartzose rocks by metamorphism. Strain-shadows are also well seen. In some of these quartzite pebbles the texture is very coarse, but there are also numerous examples of finely crystalline rocks of similar composition. In some of these foliation is conspicuous. Others show granulitic structure very well, and in many of these water-clear recrystallised felspar is probably present in addition to quartz.

There are also many fragments consisting of quartz, with or without recrystallised felspar, and abundant mica, either muscovite or a pale green biotite. No brown biotite was observed. These quartz-schists and gneisses show very well-marked parallel structure due to foliation, and they frequently occur in long narrow fragments, which are often slightly bent by subsequent pressure. Besides the strongly foliated gneisses and granulites there are also rocks having the composition of granites and syenites, which show little or no foliation. The strain-shadows which sometimes occur in the quartz of these rocks may be due to the crushing which they have undergone subsequent to deposition. There are also a few chips of well-developed granophyres, so that it is evident that a considerable part of the detritus was derived from an area of acid intrusive rocks. No undoubted basic intrusive types have been recognised. It is noteworthy that a large proportion of the felspar of these acid intrusives is of a perthitic character, and one or two fragments of a coarse microcline-perthite-pegmatite or graphic granite may be specially mentioned. A fair proportion also of the simple felspar grains show perthitic structure.

It is impossible to describe in detail the numerous rock-types of an intrusive and metamorphic character which are to be seen in these slices : it must suffice to say that the most conspicuous elements among them are a great variety of rocks which show conclusive evidence of having been derived from an area of intense dynamic metamorphism (Plate VIII.).

Rocks of hypabyssal character are much less abundant, but quartz-porphyry and porphyry can be identified. Some of these have been much crushed. However, part of these may have been lavas rather than intrusions, and in most cases it is true



PHOTOMICROGRAPHS OF ROCKS OF INGLETONIAN SERIES.

Both figures magnified 13 diameters.

A. Grit of moderately fine texture, Chapel-le-Dale Valley, chiefly composed of angular fragments of quartz and felspar. Ordinary light.

B. Coarse grit or conglomerate of Ingleton Granite Quarry. Subangular pebbles of quartzite, &c. Ordinary light.

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that the ground-mass is very fine in texture, thus suggesting rhyolites rather than hypabyssal intrusives.

Well-defined lavas are moderately common, and in particular two distinctive types may be mentioned. There are a fair number of rather large fragments of rhyolites, showing in great perfection the peculiar structure known as micropœcilitic. Others are of a trachytic character, consisting chiefly of rather ragged irregular prisms of felspar, which appears to be in most cases orthoclase or anorthoclase. One or two examples containing a good deal of chlorite are probably referable to the andesite group, but basic lavas are apparently absent.

Taking the igneous rocks as a whole, they appear to belong to an alkaline petrographical province, as shown by the common occurrence of perthite and the abundance of lavas of trachytic appearance, but of course the evidence is insufficient to establish this fact with certainty.

One of the most conspicuous elements of this conglomerate is the dark green rock of fine texture which has already been briefly referred to. This occurs in large fragments up to a foot or more in length, and it shows slight indications of cleavage. Both to the naked eye and under the microscope its appearance is suggestive of a fine-grained volcanic ash or tuff. I have compared it with specimens of pre-Cambrian tuffs in Dr. Bonney's collection, and it shows striking resemblances to the honestones of Charnwood and to the porcellanites and hornstones of the Lilleshall and St. David's districts. Besides this there are chips of slate, with more or less conspicuous cleavage, and a variety of rocks, apparently of a somewhat schistose character, showing some recrystallisation as well as rearrangement of particles. These may be classed as slightly metamorphosed sediments. Many of the rocks consisting exclusively, or almost exclusively, of quartz are so little altered that they may be described as grits, and many other sedimentary rocks of somewhat indeterminate character occur, including some with distinct parallel structure and a good deal of finely disseminated black material, which is probably carbonaceous. These may perhaps be described as graphite schists.

A few rounded fragments, consisting of calcite with twin-striations, are probably recrystallised limestone, but it is not possible to be certain that they are not due to secondary calcite deposited in small cavities.

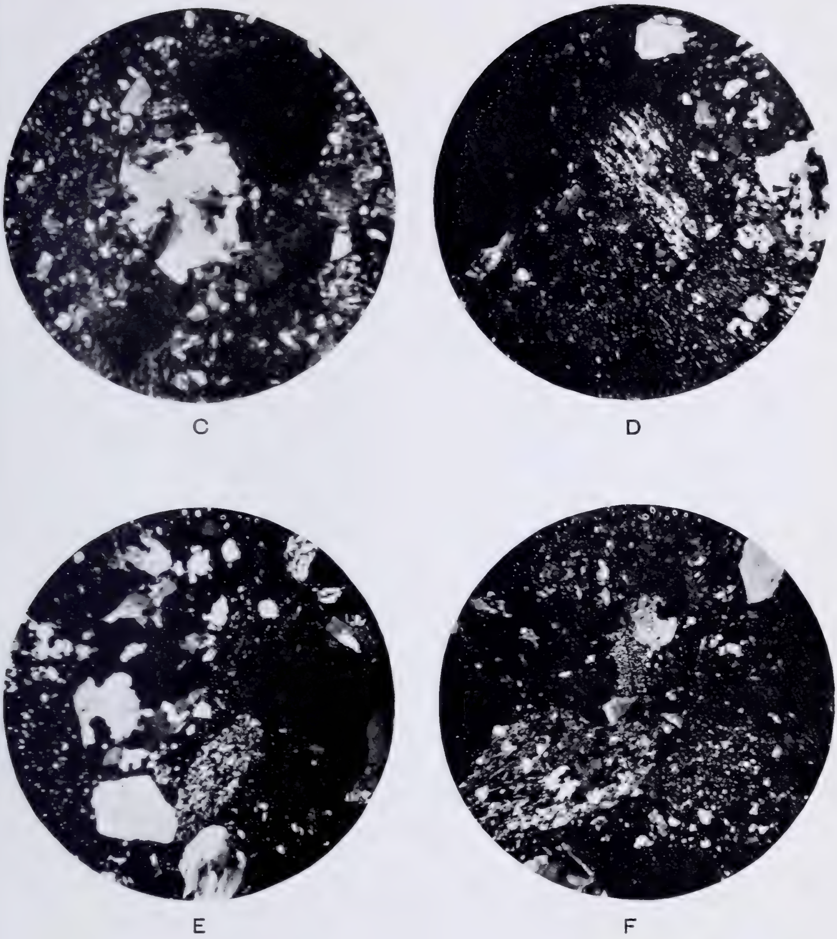
It would be easy to extend this list indefinitely, but enough has already been said to indicate the general character of the larger fragments composing this interesting rock. The smaller elements consist for the most part of more or less angular chips of quartz and felspars of several varieties, orthoclase, perthite, microcline, albite, and oligoclase.

Chlorite also is extremely abundant. It is mostly of a somewhat bright green colour, only slightly pleochroic and usually isotropic; some sections, however, having a similar appearance in ordinary light, give the interference tints of the mica group, and must be regarded as green biotite. Broadly speaking, the strongly birefringent green mineral seems to be detrital, while the isotropic or weakly birefringent variety is of secondary origin.

The Conglomerate of Row End, Horton.

At the sharp bend of the Ribble at Row End, close to Horton Station, occurs a thin bed of a rather coarser type of sediment than is usual in this valley. Although this is the lowest or rather the most northerly bed actually seen in this district, there is nothing to show that it is the base of the series. The outcrop of the Ingletonian rocks must extend for at least a quarter of a mile further up the stream, but owing to drift there are no exposures. It is more probable that this is an attenuated representative of the thick conglomerate of the Ingleton Granite Quarry. It occurs in about the position where this would be expected, and its petrographical characters are not dissimilar.

It is a rock of a general greenish-grey tint, containing pebbles up to half an inch in diameter, embedded in a fine-grained matrix, and the whole has a distinctly sheared and slickensided appearance. Owing to this crushing its original character is rather difficult to make out, but it is certainly not purely a crush-conglomerate, since it contains well-rounded pebbles of grit, quartzite, gneiss, granulite, quartz-porphyry, schist, slate,



PHOTOMICROGRAPHS OF ROCKS OF INGLETONIAN SERIES.

All figures magnified 13 diameters.

C. A fragment of metamorphic quartzite, showing strain-shadows and suture-jointing. Crossed nicols.

D. A fragment of well-foliated quartz-schist, quartzite, striated felspar, &c. Crossed nicols.

E. Pebbles of quartz, quartzite, schist, &c. Crossed nicols.

F. Near the centre is a chip of granophyre: the other fragments are of highly metamorphic rocks.

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and other easily recognisable rock-types, in addition to the usual more or less angular fragments of quartz and felspar and flakes of mica.

Conclusion.

A detailed examination of the various rock-types included in the Ingletonian series indicates clearly that the material of which they are formed has been derived from the denudation of an area of igneous and metamorphic rocks, chiefly of a schistose and gneissose character, but comprising also a variety of intrusive and extrusive rocks. The occurrence of a high degree of dynamic metamorphism is of considerable significance, since it suggests that the origin of the sedimentary material is to be sought in an Archæan complex, which was exposed to denudation during the period in which the Ingletonian rocks were formed. As we have already seen, the petrographical character of the rocks lends no support whatever to the suggested correlation with the Borrowdale series, and the apparent conformity of the Caradocian rocks on the Ingletonian is probably deceptive. All the available evidence suggests that these rocks are far older than the Ordovician, and their equivalents will doubtless eventually be found in one of the known groups of pre-Cambrian sediments, the Torridonian or parts of the Longmyndian,* or the Sparagmite of Norway. With the evidence at present at our command it is impossible to go further than this.

In his Presidential address to Section C of the British Association at Birmingham, Professor Bonney drew attention to the wide prevalence of fragments of crystalline and gneissose rocks in the later pre-Cambrian and Cambrian grits and conglomerates, and this points to the exposure of an Archæan mass over a large area. The portion of the Archæan complex from which the material of the Ingletonian rocks was derived must have been close at hand, since the fragments are in many cases too large to have been carried any great distance, and there is generally indication of rapid deposition in shallow water. This

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* It is interesting to note that so long ago as 1874 Mr. Aveline remarked on the similarity between these rocks and parts of the Longmynd series. Goodchild, Geol. Mag., 1892, p. 299.

Archæan massif probably underlies the Pennine area of the north of England at no great depth.

Finally my thanks are due to Professor Hughes for his kindness in allowing me to compare my manuscript map with his, and for other help; to Dr. Bonney and Dr. Marr for kind assistance and useful criticism; and to Dr. Dwerryhouse for several days' help and companionship in the field.

BIBLIOGRAPHY.

The following list comprises the most important references to the rocks of the Ingletonian series in easily accessible memoirs and periodicals. It makes no pretence of completeness and could easily have been greatly enlarged. In particular, many papers which deal exclusively or nearly so with the Silurian rocks of the district have been omitted :—

BONNEY.—Report of the British Association, 1886. Presidential address, Section C.

DAKYNS, TIDDEMAN, GUNN AND STRAHAN.—Geology of Ingleborough, Memoir of Geological Survey, 1890, p. 3.

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NOTES ON THE SPEETON AMMONITES.

BY C. G. DANFORD.

Anyone who knows a little about the Speeton sections can soon pick up a fairly representative series of their Belemnites, but not of their Ammonites; that demands much time and luck. Such at least has been my experience, for notwithstanding the exceptional opportunities for constant search afforded by several years' residence almost on the spot, I have not yet found some species, only poor examples of others, and —proof of the exhaustive character of Prof. Pavlow's and Mr. Lamplugh's museum and field researches—hardly any that cannot be identified from the descriptions and figures in their "Argiles de Speeton,"* to which work I am further indebted for the nomenclature and the classification of the series† used in the following slight sketch.

The Ammonites at Speeton are not only in much worse condition than the Belemnites, but also far fewer, except in the Kimeridge, where their crushed remains are legion, while in a considerable part of the upper deposits there are apparently none.

Of the 43 species described or figured in the "Argiles de Speeton,"‡ all but four, representing as many genera, are included in *Hoplites* and *Olcostephanus*, the latter being divided by Prof. Pavlow into six groups, or sub-genera, *Virgitates*, *Craspedites*, *Polyptichites*, *Holcodiscus*, *Astieria*, *Simbirskites*.

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* "Argiles de Speeton et Leurs Équivalents," par A. Pavlow, et G.W. Lamplugh, Moscou, 1892.

† The main divisions are indicated by letters, their sub-divisions by numerals.

‡ In the "Table of the Cephalopoda of the Speeton Series," ("Further Notes on the Speeton Section," &c., Q. J. G. S., vol. lii., 1896, p. 181), Mr. Lamplugh adds to these, *Hoplites Mortelleti*, Pict. and Lor., C8-11 ?, *H. interruptus* ? Brug. A., *Olcost.* (*Simbirskites*) *versicolor ?* Trautch., *Olcost.* (—) cf. *Carteroni*, d'Orb, C1 to upper part of C6 ?, *Oxynoticeras* cf. *catenulatum*, Fisch. D4-8. He also notes the probable presence in D4 of *Olcost. plicomphalus* Sow.

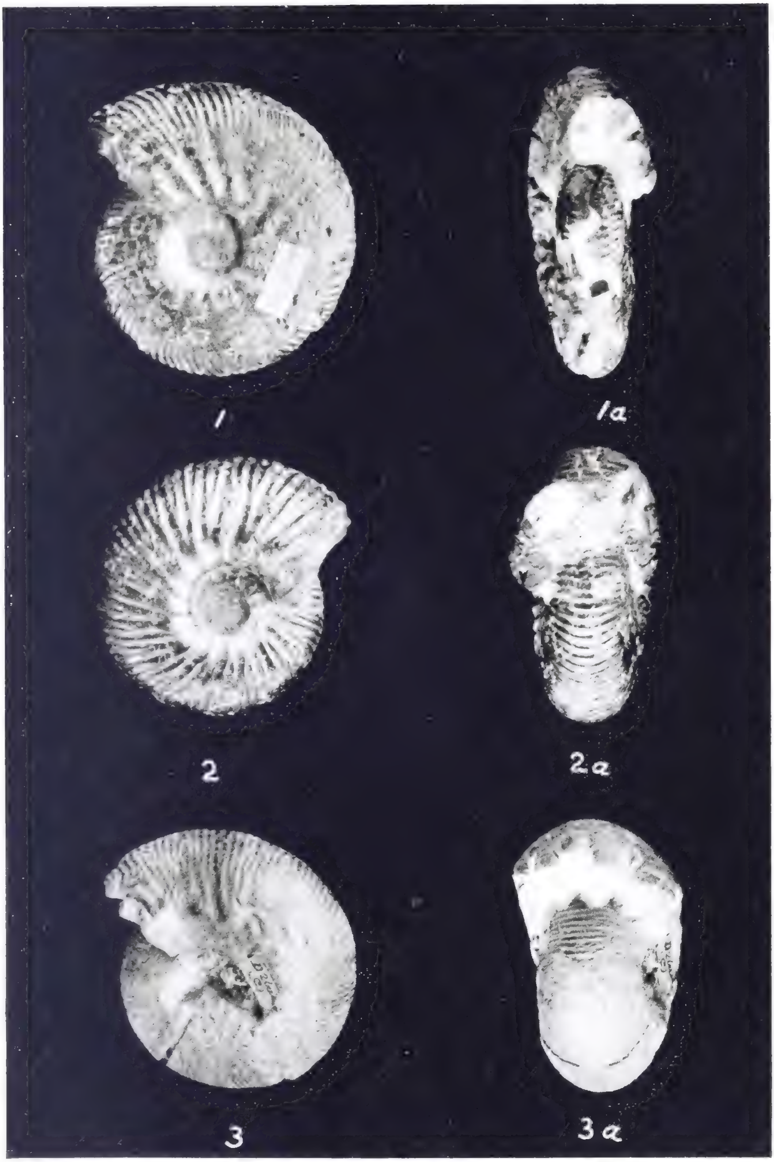
The *Hoplites* occupy the lower part of the upper Kimeridge, the extreme top of "the *Lateralis* zone" D, the lower part of "the *Jaculum* zone" C, the top of "the *Brunsvicensis* zone" B, and "the *Minimus* zone" A; the *Olcostephani*, occur in the upper Kimeridge, the Coprolite Bed E, the entire *Jaculum* zone, and the extreme base of the *Brunvicensis* zone. The species not included in these two genera occur in the Kimeridge, the middle of the *Jaculum*, and the top of the *Brunsvicensis* zones.

ZONE F (KIMERIDGE CLAY).

The greater part of the Kimeridge is *terra incognita*, for there is no record of its base and middle having been seen even by the earlier collectors, though they appear to have been vouchsafed better exposures of these shales than their successors.

The beds with *Amm. biplex* (=*Perisphinctes lacertosus*) *Amm. evalidus* (=*Hoplites eudoxus*), together with other fossils described by Leckenby, and those from which Mr. Herries subsequently collected the same species are the lowest that have been observed. Among their Ammonites preserved in various museums, Prof. Pavlow recognises *H. pseudomutabilis* Loriol and *H. subundoræ* Pavl.

During the early part of the present year there were several slight and fugitive exposures of these deposits 200 to 300 yards north of Reighton Gap, i.e., about half a mile from Speeton Middle Cliff Ridge, at the base of which the Kimeridge and the Coprolite seam above it are always more or less visible. A striking feature of the most northerly was a band of septarian nodular matter about a foot thick, which rested on greenish-black shale. This band at first showed as an almost unbroken reef, but was soon breached by the heavy seas, so that if seen again at the same spot it will not present its original continuous appearance. The beds below it were alternately greenish-black



Photographed by Godfrey Bingley, Headingley, Leeds.

Figs. 1, 1a. *Olcostephanus* (*Polyptychites*) *bidichotomus* Leym. D2 base. 17821.*
,, 2, 2a. ——— (———) *polyptychus* Keys. D2 base. 17822.
,, 3, 3a. ——— (———) cf. *Keyserlingi* Neum. & Uhl. D2 base. 17823.
Scale $\frac{1}{2}$.†

* The numbers refer to the numbers of these specimens in the Catalogue of the Geological Museum, Jermyn Street.

† Owing to a slight reduction in the making of the blocks in this and the following plates the figures representing the size of the specimens should be somewhat reduced.

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and bluish, rather hard and splintery. They contained good-sized oysters, numbers of small bivalves, and other shells ; also many Ammonites, all crushed excepting those in the calcareous pyritous nodules, which were better preserved and large, often more than a foot across. These Ammonites belong to a form of *Hoplites* apparently distinct from those above-mentioned.

The lower half of a Belemnite, found a little below the band of nodular material, afforded the only indication of the existence of that fossil at this horizon. The fragment, together with the impression left by the vanished part of the guard, showed that this Belemnite was of the *Porrectus* type, but proportionately shorter, and not the *Bel. troslayanus* found by Mr. Herries.

Another exposure at a presumably higher level seemed nearly devoid of all fossils except Ammonites of the *Perisphinctes* type—*P. lacertosus*, Dum. et Font. These, like the *Hoplites*, were much crushed, often large, and fairly well preserved only in the nodules. It is hard to say what position the beds of these isolated exposures occupy in relation to those described by Leckenby, but if this *Perisphinctes* corresponds to *Ammbiplex* they probably form part of his lowest series No. 1.

In most of the much higher beds crushed Ammonites abound, and in some near the top they occur as soft and brittle yellowish casts, indistinctly appearing to belong to round-backed forms. I have also seen detached nodules crowded with a species much resembling the figure of *Olc.* (*Perisphinctes*) cf. *miatchkoviensis* in the "Argiles de Speeton," Pl. I., fig. 6.

ZONE E (COPROLITE BED).

In the medley of materials that form this seam there are many Ammonite fragments, among which Prof. Pavlow recognised *Olc.* (*Virgitates*) cf. *scythicus* Michal., *Olc.* (—) cf. *Tchernischowi* Michal., *Olc.* (—) cf. *Panderi* d'Orb, and *Olc.* (—) cf. *dorsoplanus* Michal.

ZONE D ("BEL. LATERALIS BEDS").

In no part of this zone below the *Astarte* bed D4 have I found Ammonites, although they occur there, for Mr. Lamplugh says, "De très petits Ammonites ne sont pas rares dans la partie inférieure de la zone (D4, D5, D6, D7), mais elles sont difficiles à déterminer." These Prof. Pavlow considers resemble the inner whorls of Ammonites of the *Olc. subditus* and *okensis* types, while one form from D4 he definitely determines as *Olc.* (*Craspedites*) *fragilis* Traut.

Small Ammonites, often very well preserved, are certainly common in D4, and most of them agree with the figures and description of *Olc.* (*Crasp.*) *fragilis* in the "Argiles de Speeton,"* while others, Mr. Lamplugh thinks "are identical with *O. plicomphalus* of the Spilsby sandstone." In this bed may also be seen the remains of much larger forms, but not in a state admitting of their identification.

The next bed, D3, contains large and small Ammonites of various types. The former are generally mere crumbled masses, but some have been partially preserved by incrustations of pyrites, and their innermost whorls are occasionally intact. They appear to belong to the very globose forms of the *Polyptychites*, such as *gravesiformis*, *Keyserlingi*, &c., or to the less inflated, as *Beani*, *ramulicosta*, and perhaps to *Lamplughi*, a species here discovered by Mr. Lamplugh.

Though distributed through the whole bed, these Ammonites appear to be commonest above, and a little below the two indurated ferruginous bands that traverse it. My best specimens came from the top, and belong to *Beani* and *ramulicosta*. The deeper whorled species seem to lie generally, but not always, lower.

Among the smaller forms *Olc.* (*C.*) *fragilis* certainly occurs, and there is one in which that variation in the arrangement of the ribs where the anterior branch of the umbilical rib, after passing over the back, joins the succeeding instead of the opposite

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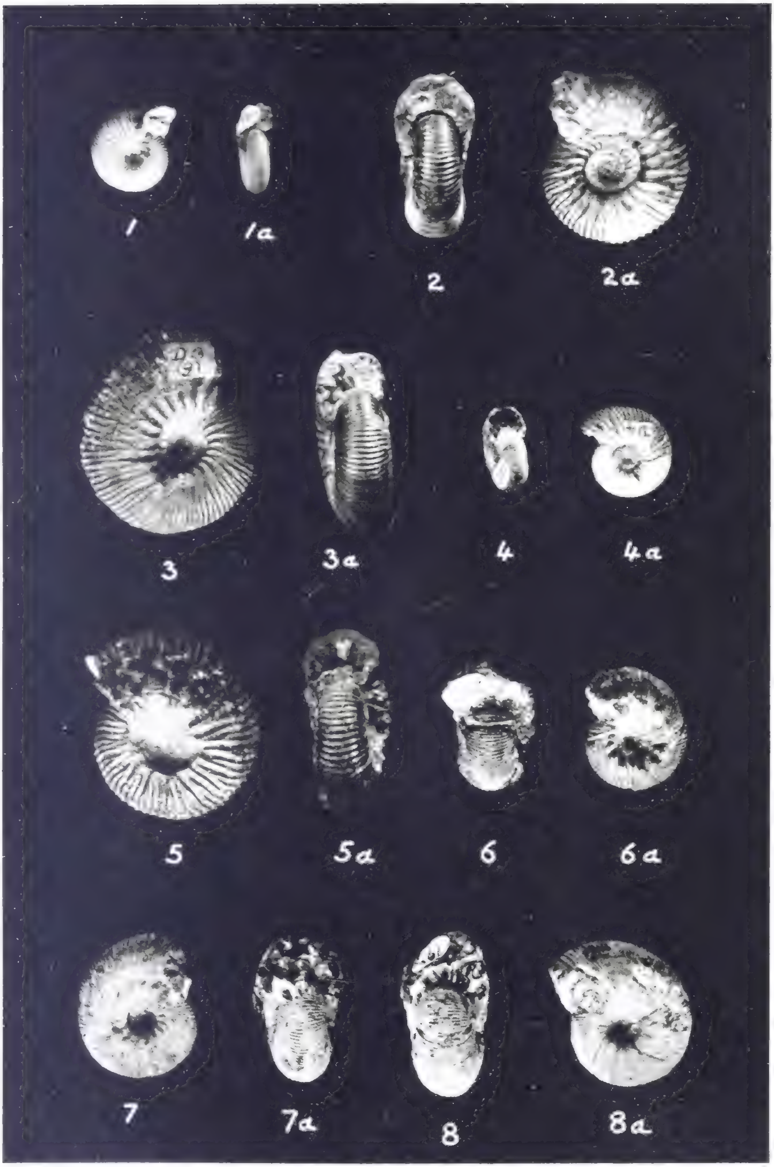
* "Argiles de Speeton," p. 15.



Photographed by Godfrey Bingley, Headingley, Leeds

Figs. 1, 1a. *Olcostephanus* (*Craspedites*) *fragilis* Traut. D2-4. 17940.
,, 2, 2a. (*Polyptychites*) aff. *Beani*. D3. 17862.
,, 3, 3a. ( ) *ramulicosta* Pavl. D3. 17863.
,, 4, 4a. ( ) aff. *Beani*. D4. 17865.
,, 5, 5a. ( ) *Beani* Pavl. D2 base. 17864.
,, 6, 6a. (*Astieria*) ? *Spitiensis* Blanf. C8-10. 17929.
,, 7, 7a. ( ) *Astieri* Sharpe C8-10. 17927.
,, 8, 8a. ( ) *sulcosus* Pavl. C8-10. 17928

Scale, Figs. 1-8, 1a-5a, $\frac{3}{4}$: 6a-8a, [illegible].

* The numbers refer to the numbers of these specimens in the Catalogue of the Geological Museum, Jerymn Street

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rib, seems to be rather the rule than the exception. In other respects this form seems to be of the *Beani* type.

It has been thought that it was from this, and the preceding beds, that the earlier collectors obtained their fine examples of the "coronated" Ammonites; but the phosphatic condition of most of their specimens, and especially of the splendid series in the Leckenby collection at Cambridge, points to these fossils having come from the base of the succeeding bed, D2, and not from D3 and D4, where, as far as my experience extends, the *Polyptychites* are, when at all well preserved, always in the pyritous state.

This bed, D2, which averages only about 2½ feet in thickness, is perhaps the most interesting of the entire series. It is formed of dark gritty clays, easily distinguishable from the yellowish-brown deposits of D3. In its upper three-fourths there are not many fossils, but the half-dozen inches of its very compact base is crowded with them, as well as with phosphatic stones, "potato nodules," and larger concretions. Most of the phosphatic lumps are partly rounded and pitted, partly flat or angular, as if the masses to which they originally belonged had after long exposure broken up, and their fragments had soon been covered by sediments. Indications are not wanting that some, if not most of them, are derived from Ammonite casts. The nodules, soft and brown outside, hard and dark within, do not enclose fossils, though Belemnites, and very rarely Ammonites, are found adhering to their softer exteriors. The concretions consist of these lumps, nodules, and a variety of fossils, often in widely different states of preservation, cemented together by pyritous materials. Ammonites both square and round-backed are here numerous, the former represented by *H. regalis*, *H. hystrix*, &c., the latter by a larger number both of species and individuals. Some of the small forms are well preserved in the ordinary condition; others, small and large, round and square-backed, are more or less crushed, mere soft clay casts, or much impregnated and encrusted with pyrites, while many are in a phosphatic state, hard, dark, and brittle.

These last are chiefly of the round-backed kind, and generally very fragmentary. Most of them seem to belong to *O.* (*Polyptychites*) *bidichotomus* and *O.* (—) *polyptychus*, but *O.* (—) *Beani* also occurs, and a very globose form, suggestive of *O.* (—) *Keyserlingi*, but with ribs finer and more numerous than in that species.

Among the fragments found there are also indications of the existence of other allied forms, some of which must have been of considerable size, as part of a whorl of the *bidichotomus* type measured nearly six inches across.

At this horizon *Lateralis*-Belemnites swarm, most of them showing signs of much exposure. There is also a slight sprinkling of *Bel. jaculum.* Other fossils, such as Pleurotomaria, Pleuromya, Pecten, Exogyra, &c., are common. Saurian remains are not rare,* and there is a good deal of fossilised wood. It is, in fact, a heterogeneous collection of materials, somewhat resembling that of the Coprolite seam. Though the rest of this bed is comparatively poor in fossils, it has yielded interesting forms, one an *Hoplites*, which quite agrees with Sayn's description and figures of *H. Arnoldi*, from the beds with *Bel. latus* at Blegiers, Basses Alpes,† which Pavlow says is not the *Arnoldi* of Pictet, and renames *heteroptychus.* This specimen is in the phosphatic state, well preserved, measures 48 mm., and has the deep constrictions (4) bordered by more strongly developed ribs that are mentioned by Sayn, but not by Pavlow in his description or apparent in his figures of *H. heteroptychus* from an unknown horizon at Speeton.‡ In the outer whorls the sculpture is irregular, as in these figures, but in the inner the umbilical ribs give rise to three, or more frequently four, branches which spring from sharply pointed and prominent tubercles,

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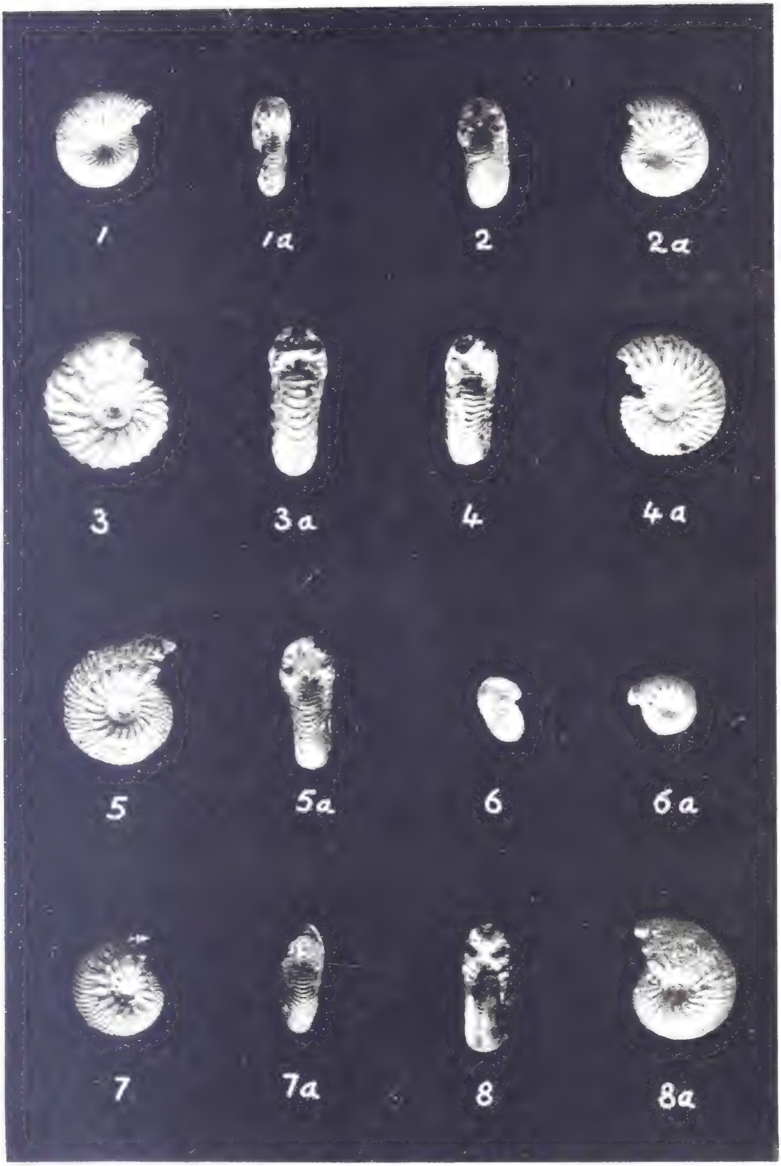
* Saurian remains also occur at the top of the Kimeridge and the base of the *Brunsvicensis* zone.

† "Notes sur quelques Ammonites nouvelles ou peu Connues du Néocomien Inférieur," Bull. Soc. Geog. France, Series 3, vol. 17, p. 682, Pl. XVII., figs. 6, 7.

‡ "Argiles de Speeton," p. 109, Pl. XI., fig. 22.



[illegible]

Figs. 1, 1a. [illegible] (Simbirskites) *Pavlowi* [illegible] C6-8. 17910.
" 2, 2a. [illegible] (") *speetonensis* Phill. C6-8. [illegible]
" 3, 3a. [illegible] (") sp. C7-8. 17930.
" 4, 4a. [illegible] (") *subinversus* M. Pavl. C7-8. [illegible]
" 5, 5a. [illegible] (") *progrediens* Lahus. C6. [illegible]
" 6, 6a. [illegible] (") *concinnatus* Lahus. C upper. [illegible]
" 7, 7a. [illegible] (") *Decheni* Roem. C upper. 17920.
" 8, 8a. [illegible] (") *discofalcatus* Lahus. B base to C upper. [illegible]
Scale [illegible]

[illegible]

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situated about the middle of the flanks. These secondary ribs are very like those of *Olc.* (*Simbirskites*) *umbonatus.*[*]

Of two other forms I have also found but single examples. Both are *Hoplites*, one being somewhat of the *H. oxygonius* type, but with ribs that bifurcate with complete regularity unusually near the back. The branch, however, is often so much detached from the main rib that it presents an intermediate appearance. The other form is more compressed, with much finer ribs, which are regularly trifurcate about the middle of the flanks, the anterior being also generally detached. These forms have not yet been determined.

The top of the zone, D1, is well marked by the line of large nodules called by Mr. Lamplugh " the compound nodular band." They have mostly been formed round big Ammonites of the *Hoplites* type, and apparently sometimes *Crioceras*, of which a large species is present in D2, but the fossils and the concretions are so worn that it is very difficult to distinguish species.

These masses consist of bluish calcareous material, in which are embedded " potato " and darker nodules, which must have been formed earlier, but not much earlier, for the main and the subsidiary concretions contain the same fossils, among which are smaller and much better preserved examples of *Hoplites regalis*, *Roubaudi* and *hystrix*, *Lateralis-* and *Jaculum-*Belemnites, Bivalves, and Crustaceans as *Myeria ornata*, but never, I think, any of the *Olcostephani*, unless some of the blacker lumps are fragments of their phosphatic casts.

As the question at what horizon these latter Ammonites ceased to exist is of some interest, I have in the cliff carefully dissected a stretch of Beds D1—D2, about 40 yards long by 2 feet wide, and in this fairly large sample have not found a trace of the round-backed Ammonites above the basal six inches of D2. The square-backed *Hoplites*, on the contrary, pervaded both beds, as did *Lateralis*- and *Jaculum*-Belemnites, the former showing a great decrease in numbers above the six inch limit, the latter an increase, slight at first, but very marked in D1.

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[*] Another specimen from the Comp. Nod. Band may be *heteroptychus*, but seems nearer *H. neocomiensis* d'Orb. It is, however, too fragmentary to be easily determined.

Shore exposures confirmed these observations, for though fragments of the round-backed forms sometimes occurred at the "compound nodular band," they were not in place, but had been washed in from the closely adjacent base of D2, and lodged among the large nodules.

The development of the Belemnite and Ammonite immigrants has here evidently been quite dissimilar, for the *Jaculum*-Belemnites, though found as low as D4, and even D5, do not attain their full strength until nearly the middle of the next zone C, whereas the *Hoplites*, which have not been met with below D2, are nowhere in greater force both as regards size and numbers than at the compound nodular band.

Certainly the *Jaculum*-Belemnites on their arrival in the north must have found a vigorous, and perhaps hostile, crowd of their kinsfolk in possession. At all events they did not multiply much until the *Lateralis* tribe had vanished, but when the square-backed Ammonites came in from the south many of the round-backed species were probably extinct, and the rest may have been on the verge of extinction. Perhaps, however, it was all a matter of changed climatic conditions, which suited the one group better than the other.

ZONE C ("JACULUM BEDS").

The most abundant Ammonite of this zone from Bed 7 to its lowest bed 11 is *Hoplites regalis*,* but whether it ranges

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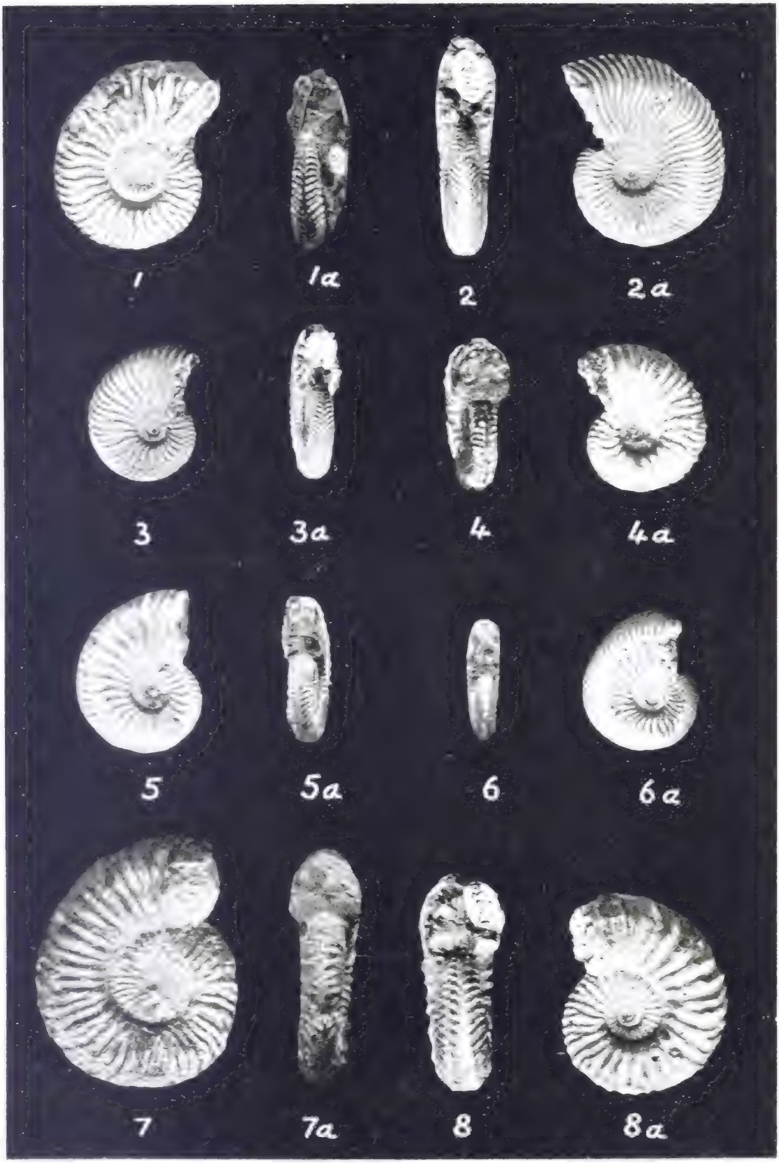
* Prof. Pavlow points out that Neumayer and Uhlig have shown that the name *Noricus*, so generally applied to this Ammonite, is a misnomer, as the species is not found near Noris (Nürnberg), and that the name was originally given by Schlotheim to an example of the genus *Cosmoceras*.



Photographed by Godfrey Bingley, Headingley, Leeds.

Figs. 1, 1a. *Hoplites Roubaudi* d'Orb. C11-D2. 17936.*
,, 2, 2a. —— *regalis* (Bean) Pavl. C7-11. 17932.
,, 3, 3a. —— *oxygonius* Neum. & Uhl. C7-11. 17933.
,, 4, 4a. —— *amblygonius* Neum. & Uhl. C lower. 17926.
,, 5, 5a. —— ? sp. D2 upper. 17937.
,, 6, 6a. —— ? sp. D2 upper. 17938.
,, 7, 7a. —— *hystrix* Phill. C11-D2. 17935.
,, 8, 8a. —— *Euthymi* Pict. C base. 17934.
Scale, 1-8, 2a, 3a, 4a, 8a, $\frac{2}{3}$; 1a, 5a, 6a, 7a, [illegible].

* The numbers refer to the numbers of these specimens in the Catalogue of the Geological Museum, Jermyn Street.

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any higher seems doubtful. In C7, at the foot of Black Cliff Ridge, it is common, but at that point the sequence of the beds along the shore is interrupted by a great landslip, and the condition of the ridge itself makes investigation there difficult.

Its near ally, *H. oxygonius*, with fewer and coarser ribs, appears to have an equally extended range. *H. amblygonius*, in which the ribs, also fewer, and coarser, form at the back an obtuse instead of an acute or right angle, as in the two preceding species, chiefly occurs in the lower beds. *H. Euthymi* easily distinguished by its three rows of prominent tubercules on each side, occupies a still lower position; while *H. hystrix*, with similar tubercles, and coarse undulating ribs, which occasionally form loops between the tubercles, and *H. Roubaudi*, with its regular arrangement of alternate simple and bifurcate ribs, appear to be confined to the immediate vicinity of the compound nodular band.

Well-preserved specimens of this group are always of very moderate size, but remains, apparently of *regalis* and its nearest allies in and near the compound nodular band, show that these Ammonites attained large dimensions, for many there measured were from one to two feet across.

The *Hoplites* are not the only Ammonites of this zone, for it is also tenanted by members of the *Holcodiscus* and *Astieria* sections of the *Olcostephani*. The former, represented by *Olc.* (*Holcodiscus*) *rotula*, is mainly met with in the lowest beds, and has been found by Mr. Lamplugh even in the compound nodular band. This species is not rare, and is sometimes rather large. The forms of the latter group, *Olc.* (*Astieria*) *Astieri*, *Atherstoni*, *spitiensis*, and *sulcosus*, occupy a rather higher position; such at least as I have found have not been near the base of the zone, certainly never in the *Lateralis* clays, where they have been said to occur, but usually near C9, the bed where the small nodules so often contain shrimps and other crustaceans, and which, owing to two distinct yellowish bands that run through it, forms a useful landmark in this often much obscured section. None of these species is at all common, but I think the least rare is a form with four constrictions, which is probably *sulcosus*.

The higher deposits of this zone are occupied by the *Simbirskites* section of the *Olcostephani*. These Ammonites first appear in C8, and are therefore overlapped by the *Hoplites*. The group here comprises 9 or 10 species, some well defined, others harder to distinguish. They are often spoken of collectively under the convenient name of *Speetonensis*, which is therefore said to be common. My own experience, however, is that true *Speetonensis* is rather uncommon, as are all the others except *inversus*, *sub-inversus*, and perhaps *concinnus*. The two first which are superficially very much alike, but differ in the pattern of their sutures, present many varieties, with ribs coarse, fine, or arranged in the zig-zag fashion already alluded to, but always simply and regularly bifurcate, while in *concinnus* some of the umbilical ribs, especially those of the inner whorls, are trifurcate.

These species occur at almost the lowest horizons occupied by this group, but are, according to Mr. Lamplugh's "Table of the Speeton Cephalopoda," preceded by *Payeri* and *versicolor*, and succeeded by *progrediens*, *speetonensis*, *discofalcatus*, *umbonatus*, and *Decheni*. The two last I have found in the topmost beds of this zone, *discofalcatus* still higher, at the base of the next zone.

In a recent memoir on the *Simbirskites* group,* Prof. Pavlow shows that the specimen with 30 umbilical ribs, described and figured in the "Argiles de Speeton" (p. 147, Pl. XI., fig. 22) as *Olc.* (*Simbirskites*) *discofalcatus*, Lahus. is not that species, which has only 19-21 umbilical ribs, but is *Simbirskites Phillipsi*, which has 24-30.

A specimen that is apparently of the true *discofalcatus* type, with only 19 ribs, was lately found by Prof. P. F. Kendall

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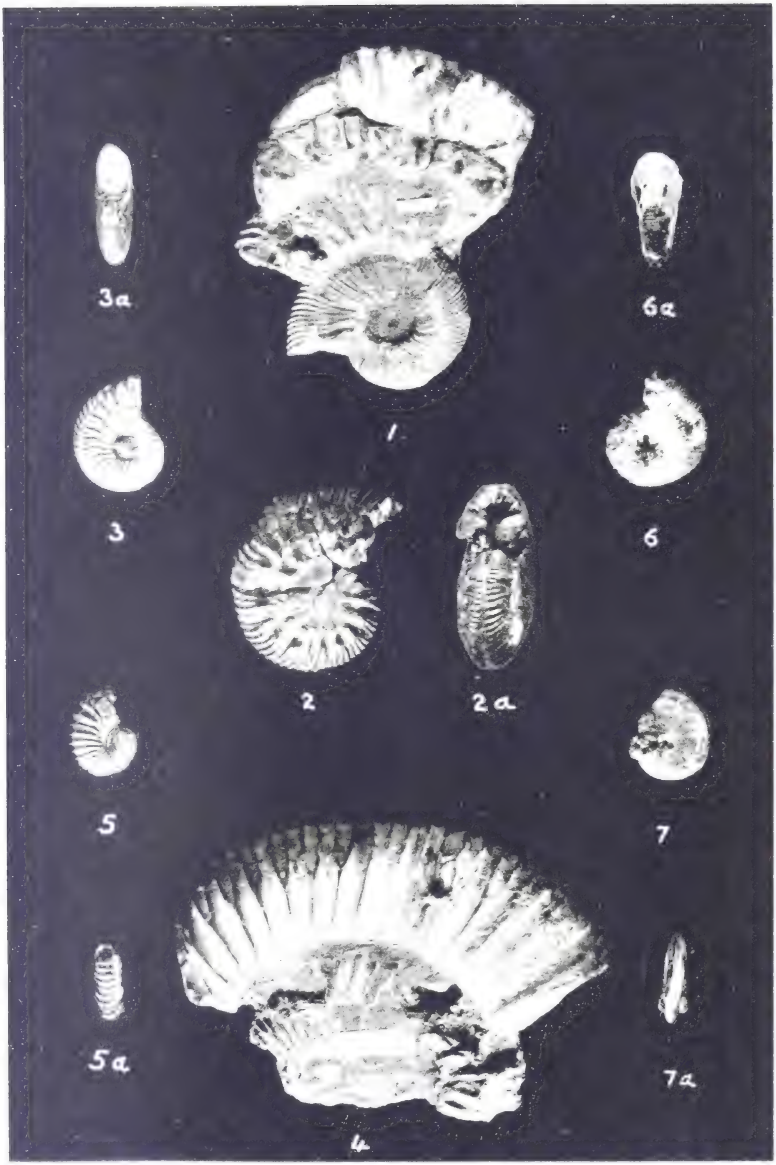
* "Le Crétacé Inférieur de la Russie et sa faune," Moscou, 1901, p. 78., Pl. VI., figs. 1, a, b, c, d; Pl. VII., figs. 2, a, b, c; 3, a, b, c.



[illegible] Bingley, Headingley, Leeds.

Figs. 1. *Hoplites* . . . sp. Base of Upper Kimeridge. 18150
" 2, 2a. ? *heteroptychus* Pavl. D2 upper. 17939.
" 3, 3a. *Deshayesi* Leym. B upper. 17915.
" 4. *Perisphinctes lacertosus* Dum. & Font. Base of Upper Kimeridge. 18151
" 5, 5a. *Acantoceras ? peltoceroides* Pavl. C9. 17925.
" 6, 6a. ?*Desmoceras* cf. *cassidoides* Uhl. C6-9. 17917.
" 7, 7a. *Oppelia nisoides* Sarasin. B upper. 17916.

Scale, 1, 4, $\frac{2}{3}$; 2, 3, 5, 6, 7, $\frac{1}{1}$.

* [illegible] refer to the numbers of these specimens in the Catalogue of the Geological Museum, Jermyn Street.

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high up on Speeton Black Cliff Ridge. It therefore appears that as in the Russian deposits both forms are here represented.

The upper part of the Jaculum-clays has, however, of late years been but poorly exposed, which partly accounts for my having found only very few of its Ammonites, and my inability to give any additional information regarding their distribution.

The remaining Ammonite genera of this zone are each represented by only a single species, *Acantoceras* (?) *peltoceroides* Pavl., and *Desmoceras* cf. *cassidoides* Uhl. Both seem to be rare, for of the former I have come across but one imperfect example near C9, and of the latter two fair specimens, one about the same horizon, the other much higher.

ZONE B ("BRUNSVICENSIS BEDS").

The soft brown nodules at the base of this zone sometimes contain specimens of *Olc.* (*Simbirskites*) *discofalcatus* or *Phillipsi* (?), but they are generally very ill preserved. Otherwise it seems to be quite devoid of Ammonites except in its uppermost beds. There *Hoplites Deshayesi* is common, but in a condition so decayed that even a fair example is a rarity. At the same horizon the small flat forms of *Oppelia nisoides* Sarasin are not rare, together with fragments of a distinct but apparently kindred species; and occasional glimpses of beds only a little lower have shown that they contain considerably larger Ammonites, very rotten, but which seem to be of the *Deshayesi* type.

ZONE A ("MINIMUS BEDS").

In the beds with *Bel. Ewaldi*, which succeed those with *H. Deshayesi*, and which it is thought may (possibly with others still unseen) constitute a separate zone intermediate between the B and A zones, no Ammonites have yet been detected, but in the *Minimus* marls Mr. Lamplugh has found *H. interruptus* Brug. If, however, more could be seen of the upper parts of the series than the patches now and again visible along the base of the cliff south of Speeton Beck, or their very partial and rare exposures on the shore, other species might doubtless be added to the meagre list that they have hitherto furnished.

NOTE ON CRIOCERAS.

The Criocerata of the Speeton clays do not seem to have been so thoroughly exploited as the other cephalopods, presumably because their forms being less compact, have been so badly preserved that even moderately good examples of most of them are rarely obtained.

Their range as at present known is from Bed 2 of "the *Lateralis* zone" to nearly the top of "the *Brunsvicensis* zone," and probably extends at least to the base of the *minimus* marls.

The form of Crioceras in D2 resembles one of large size common in the lower part of "the *Jaculum* zone," which I think has been determined as *C. Duvali*. In that zone these fossils are most abundant in the middle beds, where they sometimes lie in almost continuous bands. None is more numerous than *C. semicinctum*, and the above-mentioned large species, while among others *C. puzosianum* and *Hamites intermedius* are sufficiently common. In this zone *C. Matheroni* is also found, but apparently only in the upper beds.

In the "*Brunsvicensis* zone," though Ammonites are so rare, there are many Crioceras. A small species like *C. Matheroni* occurs at its base, and in its lower beds *C. Strombecki* is common. The somewhat higher beds, and their bands of large nodules, contain many Crioceras, but they are either very rotten or very hard to extract. The *Deshayesi* beds have also large and small forms, which do not appear to occur elsewhere. Among these are *Toxoceras Royeri* d'Orb. and two species of *Ancyloceras*, considered by Dr. A. von Koenen to be undescribed.

The only fossil of this group which I have come across at an horizon which may be above the level of "the *Brunsvicensis* zone" was in a large nodule high up on Black Cliff. This specimen seems to agree with figures of *C. fissicostatum.* Examples of *Bel. Ewaldi* found near the same spot increase the probability of this determination being correct, and of the existence of the separate zone suggested by the presence of that belemnite.

As there is so little to add either as regards species or their distribution to Mr. Lamplugh's "Table of the Speeton Cephalopoda" (op. cit), it seems unnecessary to give another list of the Speeton Ammonites, but the few identified species of Crioceras may be enumerated. Some of my specimens have been examined and determined by Dr. A. von Koenen, others compared with the figures and descriptions of his great work on the Ammonitidæ of the North German Neocomian.* There can, however, be little doubt that many additions to this list might be made by anyone well acquainted with the forms of the group.

I have in conclusion to thank Dr. A. von Koenen, Mr. G. W. Lamplugh, Mr. G. Crick, and Dr. Kitchin for their kind assistance in the determination of specimens, and Mr. W. Crofts, Mr. J. W. Stather, and Mr. T. Sheppard for their help in field and other work.

TABLE OF THE SPEETON CRIOCERATA.

*	Crioceras	Duvali d'Orb ..	C. mid-lower, to D2 ?
*	,,	semicinctum Roem ..	,,
*	,,	Puzosianum ? d'Orb..	C. mid.
	,,	raricinctum v. Koen.	C.
*	,,	Matheroni ..	C upper.
	,,	Strombecki v. Koen	B. lower.
	,,	? fissicostatum Roem.	Zone with Bel. Ewaldi ?

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* "Die Ammonitiden des Nord-deutchen Neocom (Valangine Hauterevien, Barremien und Aptien)" von Dr. A. von Koenen (Abhandlungen der Königlich Preussischen Geologischen Landesanstaldt und Bergakademie) Neue Folge Heft 24, Berlin, 1902.

*Hamites intermedius Phill.	C mid.
*Ancyloceras sp.	B top.
* ,, sp.	,,
*Toxoceras Royeri d'Orb	,,
*? Scaphites constrictus d'Orb	,,

Species marked (*) have been determined by Dr. A. von Koenen.

SECRETARY'S REPORT, 1905.

The interest of the General Meetings and Field Excursions during the past twelve months has been well maintained. In addition to the usual programme, the experiment was tried, with much success, of holding an extra General Meeting and Field Excursion at Easter in co-operation with the London Geologists' Association, by which a number of the members were enabled to study the geology of the Lincolnshire Wolds under very advantageous circumstances.

The first Field Excursion was held at Leeds on March 2nd, when Mr. E. Hawkesworth led a party to examine the deposits of high-level sands and gravels at Rothwell and Oulton. The General Meeting was held at the Church Institute, Leeds, under the chairmanship of Mr. William Ackroyd, F.I.C., F.C.S., Borough Analyst, Halifax (whose loss we have so deeply to regret), and a very interesting discussion was introduced by Mr. Cosmo Johns on the question "Is the Theory of the Formation of the Coalfields of Great Britain by Secular Upheaval and Depression Tenable ?" Ten new members were elected.

At Easter an extended Field Excursion was taken to the Lincolnshire Wolds, Louth being chosen as the centre. Mr. John W. Stather, F.G.S., acted as chairman, and Prof. P. F. Kendall and the Hon. Secretary were the leaders. The programme covered most of the Wolds, three days being devoted specially to the glacial features and three to the solid geology of the western escarpment, the beds examined varying from the Upper Chalk, which was found in several pits, to the Kimmeridge Clay, the Neocomian exposures being of exceptional interest. The Geologists' Association also held their Easter Meeting at Louth, and the fraternal intercourse with their members was of the most pleasant kind. The Yorkshire Society was welcomed on Thursday evening, April 22nd, at the rooms of the Louth Antiquarian and Naturalists' Society.

The wide extent of the glacial deposits of this district render it particularly favourable for the study of the problems which are now occupying the minds of glacialists, and there is no part of England, according to the Geological Survey, where the process of valley erosion can be better studied than on the Lincolnshire Wolds. The excursions afforded opportunities for the study of this phenomenon, and also of the recently discovered beds of Upper Chalk, and a unique development of the Neocomian rocks. On the "windy wolds" the Yorkshire Geological and Polytechnic Society commenced its Eastertide excursions from Louth on Good Friday, April 23rd, in spite of cold winds and the driving rain which alternated with brief gleams of sunshine. Undeterred by meteorological disadvantages, they enjoyed an interesting excursion, under the leadership of the Rev. W. Lower Carter, who gave lucid explanations of the features of the country visited, of which he had made a careful study. Driving through the picturesque village of South Elkington, the party visited the Chalk Pit at Boswell, and thence the party proceeded to the head of a long valley, which runs to Hatcliffe, and walked to Beesby Top, where the interesting natural features were pointed out. Two approximately parallel drainage valleys, which run seawards, are connected by a remarkable valley at right angles to them. A lake was formed through the damming of the uppermost of the two valleys by means of ice during the glacial period. When this lake overflowed, the channel at right angles was excavated by water running from one to the other of the original valleys. The overflow-channel had comparatively steep sides as though the result of more energetic erosion than in the case of the valleys it connected, and the evidences of the presence of morainic débris was found in a field near the lip of the overflow. Pursuing the journey, the excursionists saw an interesting example of a somewhat rare case of direct overflow from the head of the valley. Proceeding through East Ravensdale to Hatcliffe a remarkable series of three overflow-valleys, which successively formed the channels of a glacier lake fed by the Wold Newton Channel, was viewed. Several of these beautiful gorge-like channels were photographed, and erratics were not forgotten though no notable discoveries were made.

The Yorkshire Geological and Polytechnic Society on Saturday, April 24th, continued their field work in the neighbourhood of Louth, under more favourable conditions than those experienced on the previous day. Hubbard's Valley was the first spot visited, and here was seen a good section of the Lower Chalk, and some attention was bestowed on the terrace-like elevations at different points along the valley, which, it was suggested, were the remnants of the higher level at which the bed of a glacial overflow was cut, while the secondary valley at a lower level was the result of post-glacial denudation due to the action of the present stream. Hubbard's Valley itself constitutes a striking example of a glacial overflow due to the blocking up of the old valley of the stream, which in pre-glacial times flowed along the valley now traversed by the Lincoln to Louth Railway. According to the old theory, which is embodied in the memoir of the Geological Survey dealing with this district, the whole of the original valley of the stream which now courses between Hubbard's Hill and Fisher's Hill was filled by boulder-clay and other glacial débris, and that on the recession of the ice some local obstruction caused it to be easier for the stream to turn at a sharp angle and cut through the chalk hill. The Hubbard's Valley gorge was assumed to be the result of this, and it was also assumed that the original valley was re-excavated. The progress of glacial geology, however, has given rise to some changes of view, and Professor Kendall pointed out that there was no stream to re-excavate the old valley, as the water had been diverted, and his theory and that of his colleague is that the North Sea ice-sheet blocked the valley, caused the accumulation of a lake which overflowed along the line of Hubbard's Valley, and that the deposits in the old valley were left there on the recession of the ice. Some small valleys in the direction of Welton were then examined, and these were considered to be of prior formation to Hubbard's Valley. On the way to Welton Vale small boulders were found in the fields, including quartz-porphhry, jasper from Scotland, Scottish porphyrite, hornblende gneiss, and Norwegian rocks.

Welton Vale was considered to have been formed in almost the same manner as Hubbard's Valley, and Professor Kendall was of opinion that the overflow had filled the valley from side to side, and he pointed out how the sides of this beautiful gorge resembled the banks of a stream, with alternating steep and low bank according to the swing of the water, whereas there is no relation between the direction of the swing of the ordinary stream and the sides of the valley. Proceeding in the direction of South Elkington, the geologists visited a recently opened gravel pit, and here was found boulder-clay at the top containing greywacke from the Tweed Valley, and porphyrite, probably from the Cheviots.

Captain W. G. Smyth joined the party at the entrance to Welton Vale, and conducted them to Elkington Hall, where they were welcomed by the squire, Mr. W. H. Smyth, and hospitably entertained. On proceeding to the brickyard near Elkington Hall they found an excellent section of the Purple Boulder Clay, and here the boulders included hornblende rock, rhomb-porphyry, and laurvikite.

The party then made their way back to Louth, and visited the Charles Street clay-pit, in which is a section of the Hessle and Purple Boulder Clays, separated by a bed of sand and gravel. Cheviot porphyrite was found amongst the boulders.

At this pit the Yorkshire Society was joined by the members of the party belonging to the Geologists' Association, and in the evening a joint meeting was held at the Masons' Arms Hotel, under the presidency of Dr. A. Smith Woodward, when Professor Kendall delivered an address on "The Geology of the Lincolnshire Wolds."

He said that the rocks which would be examined by the joint associations were the uppermost beds of the Oolitic series, the Lower Cretaceous or Neocomian, and the Upper Cretaceous or Chalk series. The principal features of the wold country are carved out of the Cretaceous rocks which have a gentle easterly dip or inclination with a slight but significant undulation or arch running from Willoughby, or from the Wash and Wainfleet up to Louth. The Neocomian rocks are a series of marine sandstones, ironstones, and limestones, including the once-important Claxby ironstone. This Neocomian series displays a remarkable attenuation, thinning as it is traced in a north-westerly direction, and it finally thins out near Barnetby. The Chalk which succeeds the Neocomian is also a marine formation, and it presents in Lincolnshire a fine development at its base of the Red Chalk which characterises the country north of the Wash. Each division of the chalk is represented in Lincolnshire, but that had only become known recently. Mr. Hill, of the Geological Survey, recently found Upper Chalk fossils, and Mr. Burnett, a native of Lincolnshire now resident in Leeds, had made a very patient search, and had found a persistent band of Upper Chalk running from a place north of Louth to the Humber. He had found a characteristic Micraster and Holaster. [We may add that some of the visitors found the Micraster at the Boswell pit.] The Lower Chalk is thin, and includes a bed of pink chalk, and the Red Chalk at the base is comparable to that of Hunstanton and Speeton. The Neocomian is even more developed than in the section at Speeton. It has well marked lithological divisions, but had been much mangled by glacial agency. The Spilsby Sandstone passes abruptly from a loose, incoherent sand to hard sandstone used for building purposes, and Professor Kendall's explanation was that the former had been largely decalcified. The Spilsby Sandstone forms a well-defined stratum, particularly noticeable in the neighbourhood of Somersby, the birthplace of Tennyson. There is a particularly fine section of the Claxby ironstone, and a splendid suite of fossils is yielded by it. This would be seen on Monday, and also the Tealby Clay, which is visible in a brickyard a few yards from the railway line. Above this comes the Carstone, and the pebbles in this and the Spilsby Sandstone are of very great interest. What struck him as most characteristic of these two divisions were small and generally angular pebbles, of which he said he did not know of any British rock at present exposed which could be regarded as a possible source. They could not have travelled far, and their form suggested that they were derived from some coast-line exposed in Neocomian times. The subject was well worthy of investigation, and he was inclined to think that in Palæozoic rocks underlying East Anglia we should find their source. He had seen rocks called phthanite in Belgium which were similar. The undulation at Louth is probably based upon an ancient hill-forming fold, which forms the eastern boundary of the great coalfield from Derby to Nottingham. He had recently given reasons for believing that a large proportion of the unexhausted mineral wealth of this field underlies Lincolnshire west of the Wolds. This view had been accepted by the recent Royal Commission on Coal Supplies, and had been included by them in the estimate recently presented to Parliament. In this view an area of upwards of 1,000 square miles of Lincolnshire is underlaid by coal measures at workable depths. The time might not be far distant when Lincolnshire would be the great coal-producing area of England. The wold region of Lincolnshire is largely covered with glacial deposits, and these deposits actually cross the Wolds in the middle region.

On Monday the party took train for Withcall, and Prof. Kendall pointed out the pink band in the Lower Chalk there, remarking that it had been suggested that the colour was due to the oxidation of glauconite. He was of opinion that the marl bands were due to solution of a considerable portion of the chalk, the fossils in the marl being filled with white chalk and not with marl.

There is a particularly fine section of the Red Chalk at the western end of Withcall tunnel, through and over which the party was conducted, and here were obtained *Terebratula biplicata* and the characteristic *Belemnites minimus*. At Donnington brick-pit, where the Tealby Clay is exposed, Professor Kendall said this was the zone of *Belemnites jaculum*, but that fossil had not been found there, though he had obtained the large *Crioceras* which they got at Speeton. *Exogyra sinuata*, which is characteristic, the remains of a shrimp-like animal (*Meyeria*), and *Pecten cinctus* were found, and then the party proceeded to a pit in the Spilsby sandstone showing the characteristics alluded to in Professor Kendall's address.

The next rendezvous was the Benniworth Haven cutting, where the engineer of the Great Northern Railway had kindly caused the Claxby ironstone, which overlies the Spilsby sandstone, to be exposed. This bed is exceptionally rich in fossils, and was, in fact, the main object of the excursion. It contains curious oolitic grains of ironstone, lime having been exchanged for iron, and the predominant fossils were beautiful specimens of

Trigonia, a large *Cucullœa*, a very large *Lima*, *Astarte*, and *Belemnites lateralis*, the last-named being the zone fossil. A visit was also paid to a large boulder of porphyry at Benniworth, and another interesting boulder, full of fossils, was found before the party reached South Willingham station for the return journey. The Kimmeridge Clay at Willingham was also examined.

On Monday evening, April 26th, an exhibition of local fossils and boulders was held in the Louth Municipal Technical School by kind permission of the Mayor, and here also was held the General Meeting of the Yorkshire Geological and Polytechnic Society, Mr. John W. Stather, F.G.S., of Hull, presiding. Two new members, Messrs. G. W. B. Macturk (Hull) and J. H. Milton, F.R.G.S. (Crosby) were elected. The Yorkshire Geologists were warmly welcomed by His Worship the Mayor of Louth (Alderman Henry D. Simpson), and Mr. Stather suitably responded on behalf of the Yorkshire Society. The Rev. W. Lower Carter exhibited six-inch maps of the Lincolnshire Wolds, showing the dry valleys, and large diagrams to illustrate his views of the positions of the ice-front at the period when they were formed, and the areas of the impounded glacier-lakes of which these channels are supposed to be the overflows. Professor Kendall then gave an address on "The Glacial Geology of the Lincolnshire Wolds."

He said that the work was only in a preliminary stage, and it would take perhaps another year or longer to work out the extremely interesting problems of the glaciation of Lincolnshire, upon which diametrically opposing opinions had been expressed. There was, however, a general agreement that there is good evidence here regarding the altitude at which the land stood at the beginning of the Glacial Period. At Louth we are almost on the extreme edge of the pre-glacial sea, and all the broad band between Louth and the sea consists of materials laid down upon the old pre-glacial sea floor and banked against the old line of cliffs. But there was a much more complicated problem in the deep pre-glacial drift-filled valleys inland. He thought the evidence conclusive that the glacial deposits of Lincolnshire were the products of land-ice and not of floe-ice.

At the outset of the Glacial Period glaciers existed in Britain, the small coalesced to form large ones, and these began to protrude into shallow seas. But a new factor came into the case in the development on a corresponding scale of magnitude of an ice-sheet having its centre in the Scandinavian region. That ice-sheet gradually pressed across the North Sea, and as it advanced it began to interfere with the eastward flow of the glaciers that debouched into the North Sea. That put on a back pressure, and there was a great augmentation of the glaciers. The great ice-sheet pressed on the Yorkshire coast, and its effects could be traced to altitudes exceeding a thousand feet; but there were some striking differences between the Lincolnshire Wolds and the Yorkshire Wolds. The Yorkshire Wolds did not seem to have been overridden, but the Lincolnshire Wolds were overtopped. Whether this was due to the Lincolnshire Wolds not being so high as the Yorkshire Wolds, or whether it was to be ascribed to different thicknesses of the different portions of the ice-front, was matter for future consideration; but he was strongly disposed to think that it was a case of differences of thickness. The sheet flowed through the Wash gap and penetrated across to the Midlands, in places even overtopping the watershed of the Trent and the Warwick Avon. The deposits of this great invasion are well developed in Lincolnshire, though their precise relations are not easy to discover. During the shrinkage of the ice great lakes were held up in all the principal valleys. Evidences of such a system of lakes are seen along the whole of the eastern slope of the Wolds. The final withdrawal of the ice left Lincolnshire very different from prior to the Glacial Period, when the coastline ran along the eastern foot of the hills at Louth and near Alford. Many hundreds of square miles of land were added to Lincolnshire by the accumulation of glacial deposits on the old sea bottom. Mr. Jukes-Browne, who is so well known for the care he has displayed in the discussion, and in many cases the successful solution, of many of the problems of Lincolnshire geology, has pointed to the fact that on the western side of the Wolds is a type of boulder clay which is known as the Chalky Boulder Clay, whereas there is on the east side of the Wolds no Chalky Boulder Clay as such.

We have on this side a purple clay surmounted in some cases by a brown clay called the Hessle Clay. Mr. Carter and Prof. Kendall had suggested an explanation of this which would meet any difficulties which are presented by Mr. Jukes-Browne's. The chalk of the sea floor over which the ice passed would be in a much sounder condition than the shattered and weathered condition observed on the Wolds. As it swept over the land surface of much shattered chalk, it gathered up enormous quantities of chalk, and the materials it deposited on this side they took to be the purple clay plus the chalk. They had heard the suggestion that the boulder-clay on this side was the product of ice moving from a north-westerly direction. With that they could not agree at all, because of its being charged with chalk from the east. In Charles Street clay-pit, Louth, there was a brownish clay at the top, purple clay below, and gravels between. Mr. Stather found in his study of the boulder-clays of the Yorkshire coast that a definite assemblage of boulders characterised the upper, which had Scottish porphyrites of the Cheviot type. Sporadic examples of these could be found in the lower clay, but in the upper they were crowded. If there was one good character by which the Hessle Clay could be identified it was the assemblage of Scottish rocks. That had in Lincolnshire a double significance. It was above the purple clay, and, so far as he knew, it had not been found on the western side of the Wolds. At Kirmington we get something like the Louth succession. But at Kirmington there was a series of deposits with the estuarine mollusc *Scrobicularia piperata.* In Lincolnshire we have a peculiar boulder-clay which does not appear to have been traced into the country south of the Wash; and he threw out the suggestion that the Hessle Clay represents a more protracted glaciation of Lincolnshire than the country south of the Wash. Palæolithic implements were not found in Lincolnshire—only one was recorded at Lincoln—but further north there were signs of glacial action in the Neolithic period. It might be that the Palæolithic period of East Anglia was represented in Yorkshire by the Hessle Clay. Speaking of Hubbard's Valley, Prof. Kendall said it was a drainage channel which had been cut to such a depth that it was bound to retain the drainage after the recession of the ice. He thought that the barrier of drift in the old valley represented the moraine laid down by the ice.

A discussion followed, in which Messrs. W. Whitaker, F.R.S., H. Preston, F.G.S., and others took part. Alderman Creswell expressed the satisfaction of the members of the local society at having been invited to be present, and moved a vote of thanks to the Mayor, as Chairman of the Technical Committee, for the use of the room. Mr. Culpin proposed a vote of thanks to the Louth Antiquarian and Naturalists' Society, coupling it with the name of Mr. C. S. Carter, their secretary, for their kind attention and courteous hospitality. Mr. C. S. Carter, in replying, said that the local society had received a valuable stimulus. They had come to recognise that they had a geology exclusively their own.

Prof. Kendall, in answer to Mr. Preston, said that all they knew of ancient glaciation seemed to show that a glacier did not throw down its débris all in a heap. It carried its rock rubbish chiefly in its lower layers, and a process of shearing accompanied the advance. There was no evidence that the Wolds ever supported glaciers of their own.

On Tuesday, April 27th, the geologists explored the country between Louth and Swaby, with a view to an examination of the glacial features of the district. In this tract of country are numbers of lake channels, running in series across the country in lines, which would appear to mark stages in the recession of the ice, and examples of two types of lake-channels were seen. One type has been left dry and deserted on the recession of the ice, but the other had been cut so deeply as to become the permanent line of post-glacial drainage. Driving to Tathwell, the Eskers sand-pit and a chalk-pit were visited, and the country near Bully Hills was investigated. Near Orgarth Hill Farm a difficult problem in the formation of the valleys presented itself—described by Prof. Kendall as one of the most difficult in the Louth area, the ends of the valley appearing to have drained in opposite directions. The party walked through the beautiful channel of Haugham Bottoms, and thence to Burwell and Walmsgate, a magnificent and very clean-cut channel being seen at Deepdale Firs. Professor Kendall pointed out in the Haugham channel that as the channel curved, one side was steep and the other a gentle slope, thus presenting the appearance of the banks of a large stream, as in the case of Welton Vale, and the same kind of thing was afterwards seen at Swaby. For the steep sides he proposed to use a term suggested by Mr. J. Lomas—the "turnpool"—and the sloping side he called the "strand." At Swaby large mounds of morainic matter had been deposited.

The meeting was resumed at the King's Head Hotel on Tuesday, April 25th, when Dr. A. Smith Woodward, F.R.S., President of the Geologists' Association, expressed the pleasure it had given the members of that Association to co-operate with the Yorkshire Society, and take part in their General Meeting. Mr. Stather suitably responded. The Hon. Secretary read a paper by Mr. J. R. Mortimer, of Driffield, on "The Genesis of the Yorkshire Chalk," which was followed by an interesting discussion, in which Messrs. W. Whitaker, P. F. Kendall, A. Smith Woodward, A. H. Davis, and W. L. Carter took part. A vote of thanks to the chairman concluded the meeting.

On Wednesday the party drove to Market Rasen, in order to further examine the Neocomian deposits and the Kimmeridge Clay. The descent of the Cretaceous escarpment near Willingham presented opportunities for the examination of exposures of Red Chalk, Tealby Limestone, and Spilsby Sandstone, the Tealby Limestone containing examples of *Pecten cinctus* and *Exogyra sinuata*, the same fossils as were found when the party visited the Tealby Clay at Donington-on-Bain brick-pit. The famous exposure of the Kimmeridge Clay was visited. The fossils here are in exquisite preservation, the most common being *Astarte*, *Nucula*, *Corbula*, *Thracia*, *Trigonia*, *Inoceramus*, *Arca*, *Cerithium*, *Neritopsis*, and many species of *Ammonites*. the last-named generally displaying a rich nacreous lustre, The party also drove to Claxby to examine the old ironstone workings along the escarpment, and separated with many felicitations on the interesting and enjoyable united excursion.

The third General Meeting and Field Excursion were held at Thirsk as a centre for a two days' investigation of the western slopes of the Hambledon Hills from Kirkby Knowle to Lower Kilburn, including the chief beds of the Middle and Lower Oolites, the Upper Lias, and interesting glacial features.

The party proceeded by wagonette to Kirkby Knowle, *via* South Kilvington and Upsall, where exposures of the Dogger and the Millipore Bed were found on the hillside. The latter showed lustre-mottling.

From the northern face of Woolmoor an extensive view was obtained of the Hambledon escarpment, showing a fine succession of terraced hills, one bed after the other having been stripped away by weathering.

A short stay was made in a gravel-pit at Kirkby Knowle, where an interesting assemblage of rocks was found, including Yoredale Limestones and Cherts, Carboniferous Limestone with encrinites and corals, Lake District andesitic lavas and ashes. The slope to Brockholes was then climbed, in which a fine section of the Grey Limestone and Middle Estuarine beds was seen, the steep face being due to an extensive landslip. On climbing to the top of the escarpment a splendid view was obtained over the vale of York and the vale of Mowbray, and extending up the whole length of Wensleydale, with the bold cliff of Penhill Beacon standing out prominently. Over the lower spurs of the Pennine Chain could be seen the masses of great Whernside and Buckden Pike. Descending to a wide overflow-channel running between Kirkby Knowle and the moorlands, the Knowle was ascended to visit a quarry in the Estuarine Sandstones in which quantities of Equisetum were found, one specimen being 10 or 12 feet in length. A lateral overflow channel was followed at Stonecliff Wood, near Pallett Hill, and the wood traversed to see the southern outlet of the fine glacier-channel at Wandhill Wood. A new cutting for the road revealed an excellent section in boulder-clay, with many cherts and scratched pebbles of Carboniferous Limestone.

A return was then made to Feliskirk, and a visit paid to the church, with its noble Norman apse and beautiful Knight Templar monument. The party returned to Thirsk by wagonette.

The General Meeting was held at the Fleece Hotel, under the presidency of Robert Bell Turton, Esq., of Kildale Hall. Mr. Isaac Hodges, of Normanton, was elected a member. After an address by the Chairman, he proposed a sympathetic resolution with the family of the late Mr. William Ackroyd, F.I.C., F.C.S., of Halifax, formerly a member of the Council of the Society. The deep regret of the Society at this serious loss to its membership was also expressed by the Hon. Secretary, and carried by the members rising.

Professor Kendall, F.G.S., then delivered an address on "Problems in the Physical History of the Cleveland Area." The rocks of Cleveland are bent into an arch or anticline, the ridge of which runs from Carlton to Robin Hood's Bay. This arch produced westwards is continued in an anticline just north of the valley of the Swale. There was an arching of the Millstone Grit and older rocks between the valleys of the Tees and Swale before Permian times, and the Millstone Grit was worn off before the Permian rocks were laid down. There was a further movement along this line in post-Permian times. Again at the close of the Lias there was another movement sharpening the same arch. In most places the Dogger, the lowest beds of the Oolites, lies upon the Upper Lias.

Notwithstanding this, in some areas Upper and Lower Lias fossils have been found in the Dogger, showing that in some unknown area there must have been a very extensive denudation of the Lias prior to, or during, the deposition of the Dogger. In some areas, however, the Dogger entirely disappears, seeming to show contemporaneous erosion. The Coxwold-Gilling Gap is due to the letting down of a narrow strip of rock by two parallel faults, which can be traced across the vale of York as far as the Ure, but then are lost below thick drift deposits. These faults seem to be part of a system of faults that runs across Malham to Ingleton, continued by those bounding the Vale of Eden, and again by the Tyne faults which run to sea at Tynemouth. This system of faults in the Vale of Eden and North Yorkshire shows movement in Carboniferous and Post-Carboniferous times, but cannot be proved to have moved again until subsequent to the Kimmeridge Clay period.

in the Coxwold-Gilling faults. There is no Dogger on each side of this faulted zone, and the Cornbrash, usually one of the most persistent rocks in Britain, is also wanting in the Coxwold-Gilling area, and in addition the Oxford Clay, which is a most obstinately persistent rock, can be traced as far south as Whitestone Cliff, and then only reappears south of the Coxwold faults. This evidence may point to subsequent movements of these parallel faults.

Professor Kendall then mentioned the chief lines of evidence by which he was led to fix a line along the western slopes of the Hambledon Hills for the obstruction of the drainage by the Vale of York glacier, and the formation of marginal lakes and their drainage channels. Referring to two overflow channels in the Kirkby Knowle area, he pointed out the evidence for a readvancement of the ice towards the close of the glacial period. This, he explained, quite corroborated evidence obtained in Cleveland, Lincolnshire, and on the eastern side of the Pennine Chain. Mr. Hall, of Thirsk, explained that glacial boulders had been found at considerably higher elevations than the channels mentioned. The discussion was continued by the Chairman, Messrs. Hastings, Carter, Johns, Ashworth, Hawkesworth, and Stather.

A hearty vote of thanks to Mr. Turton for presiding, and to Professor Kendall as lecturer and leader, was passed on the proposition of Rev. C. T. Pratt, seconded by Mr. E. Hawkesworth.

On Saturday morning the party drove to Low Kilburn, getting splendid views by the way of the precipitous face of Roulston Scar and the well-known "white horse" on its flank. The outline of that interesting physical feature, Gilling Gap, formed by two parallel east and west faults, was plainly seen. The evidence for the northerly of this pair of faults was sought in quarries on the flanks of Snape Hill, Corallian Limestones, with ammonites, being well shown on the southern or downthrow side, and the Upper Lias in another quarry a little to the north of the northerly fault, giving a downthrow to the south of 600 or 700 feet. From the top of Snape Wood a magnificent view was obtained of the grand escarpment of the

Hambledon Hills, and the leader was not only able to point out the solid geology very effectively, but also the localities at which the glacial overflows trench the lower parts of the ridge.

Ascending Hood Hill an exposure of the Hydraulic Limestone (Lower Oolite) was examined, showing the decalcification of the limestone running across the bedding. Above this, on the 725-foot contour, a moraine was found full of cherts, andesites, and other foreign rocks. On the summit of Hood's Hill is the Lower Calcareous Grit full of the ramifying concretions that characterise it at Filey Brigg. The summit is trenched with earthworks in a peculiar manner.

Crossing the steep valley between Hoods Hill and Roulston Scar, which may have been a lake-channel, but the landslips from both sides have considerably masked the original shape of the valley, the steep face of Lower Calcareous Grit was reached under which is the Kellaways Rock without any Oxford Clay. After a short rest on the top of the Scar to regain wind and enjoy the far view, a rapid descent was made to Gormire, a curious little lake in an overflow channel under Whitestone Cliff. The evidences of landslips are so numerous all round Whitestone Cliff that it is fairly evident that the channel at both ends of Gormire has been blocked by slipped material, impounding the drainage, and terraced landslip ridges can be traced up the cliff face. Parallel to the Gormire westwards are two other overflow-channels exactly imitating the curve of the Gormire channel, which form a most interesting example of a series of glacier-lake channels, draining the water impounded by the ice at three stages of its advance or retreat. Finally a visit was paid to a fine section in the Dogger and Lower Estuarian series at Cleaves, whence the party returned by wagonette to Thirsk, after a most instructive and enjoyable excursion, in perfect weather.

The fourth General Meeting and Field Excursion were held at Middleton-in-Teesdale on July 21st and 22nd, under the presidency of Mr. William Gregson, F.G.S., and the leadership of Mr. Arthur R. Dwerryhouse, M.Sc., F.G.S.

The party drove on Friday from Middleton to High Force, where the sections of the Whin Sill and of the underlying limestones were examined. Here several thin beds of carboniferous shale lying within the mass of the dolerite were seen, and specimens of these shales, which are highly altered, were taken for subsequent microscopical examination. A walk along the bed of the Tees above High Force, during which several exposures of the Whin Sill were examined, brought the members to an exposure of Skiddaw slates, which lies on the bank of the river at the foot of Cronkley Scar. The rocks were found to be highly contorted, and to be penetrated by dykes of mica-trap.

Cronkley Gorge was then traversed, several glacial moraines being seen on the way, and an examination of the basement conglomerate of the Carboniferous system made. The dolerite rocks of Cauldron Snout were then studied, and the members returned by way of Thistle Green and White Force to High Force, whence they drove to Middleton.

On their return the members dined together, after which the General Meeting was held, under the presidency of Mr. W. Gregson. Mr. Samuel Margerison, of Calverley, was elected a member of the Society. The Chairman gave an interesting address, dealing with the archæology of Teesdale, describing in the course of his remarks the two types of barrows which had been opened in the dale, the extinct and rare wild animals of the district, and the Roman remains. Mr. J. T. Sewell read a paper on "New Sections in the Pickering Delta," in which he dealt with various matters related to the glaciation of the district, and brought forward evidence that one at least of the glacial lakes had stood at a level considerably higher than had been previously supposed. Mr. Dwerryhouse gave an address on the general geological structure of Upper Teesdale, after which some interesting sections of the trenches made in connection with the Stockton and Middlesbrough Waterworks were exhibited by Dr. W. Y. Veitch, of Middlesbrough. Geological specimens from Australia were exhibited by the Chairman.

The party proceeded by coach on Saturday through Lunedale to Grains-o'-th'-Beck Bridge, near the summit of the Upper

Pass of Stainmoor. Here sections in the glacial deposits were examined, and were found to contain rocks from the Lake District, the Eden Valley, and the South-west of Scotland, together with much material of local origin. After examining these sections the members examined a number of glacial overflow channels in the neighbourhood of Wemmergill Hall, and returned on foot to Middleton.

The Council regard with much satisfaction the completion and publication of the Underground Waters Report, which was issued to the members in Vol. XV., part 2, of the Proceedings. A special fund was privately raised to meet the heavy expenses of the maps, plans, and photographs for its illustration, and the sum of £58 14s. 6d. was subscribed, which enabled them to adequately fulfil this task without intrenching upon the ordinary income of the Association.

The Council regret the resignation of Mr. Robert Reach, for many years Local Secretary for Harrogate, on account of his removal to the South of England. For the vacant Local Secretaryships at Huddersfield and Middlesbrough the Council nominate Messrs. Alfred Sykes and W. Y. Veitch, F.G.S.

The loan of £350 to the Halifax Corporation at 3½ per cent. fell due for repayment in the spring. An offer to renew the loan for another five years on the same terms was accepted by the Council.

The question of the title of the Society has been under the careful consideration of the Council. It has been represented by members from time to time that the words "and Polytechnic" are antiquated and refer to bygone times when the work of the Society, in addition to Geology dealt largely with Mining, Metallurgy, Archæology, and Agricultural Improvement. The formation of separate societies for the consideration of these allied subjects has left the Society to its proper function of dealing with Geological Science in its various branches. The Council feel that the time has now come when this change should be recognised by a corresponding alteration in the title of the Society, and have given the necessary notice to place a resolution before the members at the present Annual General Meeting to amend Rule 1, so that the title shall in future read "The Yorkshire Geological Society."

On account of the meeting of the British Association being held in South Africa this year, the meeting of the Corresponding Societies Committee was held in London on Monday and Tuesday, October 30th and 31st, which the Hon. Secretary attended as a delegate of the Society. An important paper was read at the first meeting by W. Martin, Esq., M.A., LL.D., on "The Law of Treasure Trove," and a discussion took place on the question of copyright as affecting papers published in scientific journals and lectures before societies. At the second meeting Professor G. S. Boulger gave an address on the preservation of our native plants, which initiated a valuable discussion as to the depredations due to the ravages of dealers and greedy scientific collectors, and to the necessity of legal protection for ferns and wild flowers, and of education of teachers and school children on the beauty of our native flora and the need of care against its extermination.

The following General Meetings and Field Excursions are recommended for the year 1906 :—

1. Leeds, about the end of February.
2. Helmsley, for the Howardian Hills and the Valley of the Rye.
3. Buxton or Matlock, for North Derbyshire.
4. Annual Meeting at Sheffield, with a Field Excursion on the following day.

The Council sincerely regret the loss by death of Mr. Thomas Walshaw, of Wakefield ; Mr. William Ackroyd, F.G.S., F.C.S., Borough Analyst of Halifax a valued member of Council and the contributor of important papers to our Proceedings ; Mr. George Bray, of Leeds, who took a deep interest in the work of the Underground Waters Committee. and contributed generously to the funds raised for the earlier investigations ; Colonel H. Trench-Gascoigne, who had been a member of the Society for thirty years ; Mr. W. Myers Beswick, of Filey, and Mr. John T. Pearson, of Melmerby. Membership of the Society, as reported at York twelve months ago, was 186. During the year 18 new members have been elected, 6 have been removed by death, and 6 have resigned, leaving the membership at the beginning of this meeting at 192, a gain of 6 on the year.

Our Proceedings have been forwarded to the following Libraries and Scientific Societies in exchange for their publications :—

British Museum, Copyright Office.
British Museum (Natural History).
British Association.
Patent Office Library, London.
Royal Dublin Society.
Royal Geographical Society.
Royal Society of Edinburgh.
Royal Physical Society of Edinburgh.
Royal Society of Tasmania.
Royal Society of New South Wales.
Australian Museum, Sydney, N.S.W.
Department of Mines, Sydney, N.S.W.
Australian Association for the Advancement of Science, Sydney, N.S.W.
Department of Mines, Adelaide, South Australia.
Geological Society of Australasia, Melbourne, Victoria.
Nova Scotian Institute of Science.
Natural History Society of New Brunswick.
Royal Institution of Cornwall, Truro.
Royal Geological Society of Cornwall, Penzance.
Bradford Historical and Antiquarian Society.
Bristol Naturalists' Society.
Birmingham Natural History and Philosophical Society.
Cambridge Philosophical Society.
Essex Naturalists' Field Club.
Edinburgh Geological Society.
Geologists' Association, London.
Geological Society of London.
Hertfordshire Natural History Society, Watford.
Leeds Philosophical and Literary Society.
Leeds Geological Association.
Liverpool Geological Society.
Liverpool Geological Association.
Hampshire Field Club.
Hull Geological Society.
Hull Scientific and Field Naturalists' Club.

Manchester Geological Society.
Manchester Geographical Society.
Manchester Literary and Philosophical Society.
North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
Nottingham Naturalists' Society.
Rochdale Literary and Scientific Society.
Southport Society of Natural Science.
Warwickshire Natural History and Topographical Society.
University Library, Cambridge.
University Library, Glasgow.
Bodleian Library, Oxford.
Radcliffe Library, Oxford.
Yorkshire Naturalists' Union.
Yorkshire Philosophical Society, York.
American Philosophical Society, Philadelphia, U.S.A.
American Museum of Natural History, New York, U.S.A.
Academy of Natural Sciences, Philadelphia, U.S.A.
Academy of Sciences, St. Louis, Mo., U.S.A.
Brooklyn Institute of Arts and Sciences, N.Y.
Boston Society of Natural History, Boston, U.S.A.
Rochester Academy of Sciences, Rochester, N.Y.
Kansas University, Lawrence, Kansas.
Wisconsin Geological and Natural History Survey, Madison, Wis., U.S.A.
Geological Survey of Minnesota, Minneapolis, Minn., U.S.A.
California State Mining Bureau, San Francisco.
Chicago Academy of Sciences.
Maryland Geological Survey, John Hopkins University, Baltimore, U.S.A.
Museum of Comparative Zoology at Harvard College, Cambridge, Mass.
New York Academy of Sciences, New York.
United States Geological Survey, Washington, D.C.
United States National Museum, Washington, D.C.
Elisha Mitchell Scientific Society, University of N. Carolina, Chapel Hill, U.S.A.
University of California, Berkley, California.
Meriden Scientific Association, Meriden, Conn., U.S.A.
New York State Library, Albany, U.S.A.
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W. Lower Carter.

THE YORKSHIRE GEOLOGICAL SOCIETY.

Statement of Receipts and Expenditure, October 31st, 1904, to October 31st, 1905.

REVENUE ACCOUNT.

Dr.

1904.	Receipts.	£	s.	d.
Oct. 31	To Balance in Bank		19	6
1905.				
Oct. 31	,, Life Members' Subscriptions transferred from Capital A/c	18	18	0
	,, Members Annual Subscriptions	76	14	0
	,, Sale of Proceedings	25	4	0
	,, Halifax Corporation, Interest on Mortgage Bond	11	12	10
	,, Special Subscriptions for publication of Report of Underground Waters Committee...	53	14	6
		£187	2	10

Cr.

1905.	Expenditure.	£	s.	d.
Oct. 31	By Meetings and Excursions	13	19	6
	,, Cost of Proceedings (Chorley & Pickersgill, Ltd.)	121	13	7
	,, Sundry Printing, Stationery, Circulars, &c. (Carter)...	26	12	2
	,, Hon. Secretary's Postages and Petty Cash...	9	17	1
	,, Stanford, Maps	9	8	9
	,, Griffin, Year Book	0	6	0
	,, G. H. Parkes, Set of Proceedings	5	0	0
	,, Balance in Bank	0	5	9
		£187	2	10

CAPITAL ACCOUNT.

1905.		£	s.	d.
Oct. 31	To Halifax Corporation Mortgage Bond ...	350	0	0
	,, Life Members' Subscriptions	18	18	0
		£368	18	0

1905.		£	s.	d.
Oct. 31	By Transfer to Revenue A/c	18	18	0
	,, Balance, Halifax Corporation Mortgage Bond	350	0	0
		£368	18	0

Halifax, November 1st, 1905.

I hereby certify that I have duly audited the above accounts and have examined the vouchers, and found them to be correct.

WM. SIMPSON, *Auditor.*

J. H. HOWARTH,
Hon. Treasurer.

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1906 Robinson, W. J., 54, Cardigan Lane, Leeds.

1901 Roebuck, W. Denison, F.L.S., 259, Hyde Park Road, Leeds.

1903*Rowe, Arthur W., M.S., M.B., F.G.S., 1, Cecil Street, Margate.

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1869*Rowley, Walter, F.G.S., F.S.A., 20, Park Row, Leeds.

1882 Scarborough Philosophical Society, The Museum, Scarborough

1905 Sewell, J. T., Chubb Hill Road, Whitby.

1897*Sheppard, Thomas, F.G.S., 392, Holderness Road, Hull.

1906 Sibson, Ernest E. O., 7, Lax Terrace, Norton, Stockton-on-Tees.
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1902 Thompson, Professor G. R., B.Sc., The University, Leeds.
1905 Thompson, Herbert, B.Sc., The College, Saltersford Hall, Holmes Chapel, Cheshire.
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1899 UTTLEY, WILLIAM H., 63, Hollins Grove, Sowerby Bridge.

1905 VEITCH, W. Y., L.R.C.P., L.R.C.S., F.G.S., 6, Southfield Villas, Middlesbrough.

1905*VICKERS, T. E., C.B., M.Inst.C.E., M.I.Mech.E., River Don Works, Sheffield.

1905 WADSWORTH, Rev. H., F.R.M.S., The Grange, Wadsley Bridge, Sheffield.

1905 WALKER P., Old Corn Exchange, Wakefield.

1906 WALKER, WILLIAM, H.M. Inspector of Mines, Doncaster.

1884*WALMSLEY, A. T., M.Inst.C.E., F.S.I., F.K.C., Engineer to the Dover Harbour Board, 9, Victoria Street, London, S.W.

1894 WALTON, F. FIELDER, F.G.S., L.R.C.P., 19, Charlotte Street, Hull.

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⁂ It is requested that any Member changing his residence will communicate at once with the Hon. Secretary.

Vol. XVI.] [Part II.

PROCEEDINGS

OF THE

YORKSHIRE GEOLOGICAL SOCIETY.

Edited by ARTHUR R. DWERRYHOUSE, D.Sc., F.G.S.

1907.

THE PALÆONTOLOGICAL SUCCESSION OF THE CARBONIFEROUS ROCKS IN THE SOUTH OF THE ISLE OF MAN.

BY WHEELTON HIND, M.D., B.S., F.R.C.S., F.G.S.

INTRODUCTION.

I have been making sporadic visits during the last few years to the south of the Isle of Man with the object of working out the succession of the Carboniferous rocks developed there, and to ascertain what correlation, if any, they had to the Carboniferous rocks on the mainland.

Certain details soon became clear. The Poolvash limestones and *Posidonomya* or black marble beds, could be at once recognised by the peculiar faunas which they contain as being the palæontological equivalents of well-known horizons in N. Wales, the Midlands, and S.W. Yorkshire. It was also recognised that at Derbyhaven and Langness there was a basement conglomerate which rested on the upturned edges of the Manx slates, and was succeeded by well-bedded fossiliferous limestones.

Cumming showed as long ago as 1848 that the Carboniferous Series in the neighbourhood of Castletown could be divided into four sub-divisions :—

The Posidonian schist = *Posidonomya Becheri* beds.
Poolvash Limestones.
The Lower or Castletown Limestones.
Basement conglomerate.

But the series is not as simple as this classification would suppose.

While the basement conglomerate is undoubtedly overlaid by well-bedded limestones at Derbyhaven, Langness, and Port St. Mary, the relation of the so-called Lower Limestones to the Poolvash series of richly fossiliferous, obscurely bedded, dome shaped, white, limestones is nowhere seen, but the latter are apparently overlaid by the *Posidonomya* beds.

The so-called Lower Limestones are to be seen at Derbyhaven and Ronaldsway, Langness, Castletown, Scarlet, Strandhall, Port St. Mary, and Ballasalla.

At Scarlet these beds pass up into Black Limestones and shales with a fauna which shows them to equal a part of the *Posidonomya* beds. So that without evidence of unconformity the Scarlet Limestones and the Poolvash Limestones are overlaid by beds of the *Posidonomya* series. Unfortunately, from one point of view, the ground between Scarlet and Poolvash is occupied by a series of volcanic ashes and lavas which renders further stratigraphical evidence impossible, and the present paper is an attempt to settle the question by an appeal to palæontology.

The question whether the Derbyhaven-Ronaldsway series represents a series much older than that of Scarlet, has been much on my mind, for there being a gap in the series between Langness and Castletown, there is no stratigraphical reason why the beds at Langness and Castletown might not be the Lower and Upper members of a fairly extensive series and agree with the sequence of Arnside, West Yorkshire and Westmorland, which have beds with *Michelinia megastoma* at the base, with a fauna which points to a *Seminula* and Upper *Caninia* horizon.

However, if *Zaphrentis Enniskilleni* is to be used as a zonal form, and hitherto it has seemed always very definitely to indicate an Upper *Dibunophyllum* fauna, as I have shown above, then we must regard the Derbyhaven beds as high in the *Dibunophyllum* zone, a conclusion supported by the apparent identity of the coral fauna of all the limestones in the south of the Island.

It must be confessed that the whole faunal character of the Derbyhaven and Castletown limestones is peculiar, and I do not know any locality on the mainland with which to compare it.

Michelinia megastoma elsewhere is most abundant at a lower horizon, but a form of this species also occurs in typical *Dibunophyllum* beds at Clitheroe. Although the Scarlet beds are undoubtedly of Upper *Dibunophyllum* age, Dibunophyllids are practically absent, and Zaphrentid corals with *Cyclophyllum* are the dominant forms. The latter coral, however, always indicates a high horizon.

At Bradbourne, in Derbyshire, the *Zaphrentis* beds contain *Prolecanites compressus*, and are immediately underlain by limestones containing *Michelinia tenuisepta* in profusion.

Mr. G. W. Lamplugh, in his masterly memoir on the Geology of the Isle of Man, found it impossible to advance on Cumming's sub-division, and I have nothing to add to his careful and detailed work on the stratigraphy of the Carboniferous series in the south of the island. Nor could more have been done at the time his work was published from the palæontological side. Nearly all the detailed knowledge which forms the palæontological argument now was wanting at that time.

I was kindly permitted to contribute two pages of palæontological notes—pp. 254-256—to that memoir, in which I drew attention to the fauna of the *Posidonomya* shales, pointing out its identity with the fauna which characterises the shales in the Bolland and Craven areas of Yorkshire, and the Lower Culm beds of North Devonshire, and Germany. I have since that date shown that between certain parallels of latitude the shale series which succeeds the Visean Limestones always contains at its base *Posidonomya Becheri* and a definite fauna and flora.

I have been able to demonstrate this faunal sequence from the west coast of County Clare* to Clavier, near Dinant, in Belgium.†

In co-authorship with Mr. J. A. Howe‡ I proposed the name Pendleside series for these beds, the base of which is marked by the presence of *Posidonomya Becheri*, with a goniatite fauna, which later I have shown to be the homotaxial equivalent of the Lower Culm of North Devon.§

POSIDONOMYA BECHERI BEDS.

The *Posidonomya Becheri* beds form the highest Carboniferous rocks in the south of the island, and they are well exposed at Poolvash in the old black marble quarry and on the foreshore below, and to a slight extent on the bank opposite the Stack of Scarlet (Plate XV). At the latter locality I obtained *Phillipsia Polleni* and Zaphrentid corals, and these beds must come on immediately above the top beds of Scarlet quarry. Some few feet of dark limestones with chert are found interbedded with the volcanic ash a little west of Close ny Chollagh. Here and there in the volcanic ash are seen fossils. I obtained Zaphrentid corals, *Fistulipora minor*, M'Coy, *Retzia ulotrix*, and casts of *Loxonema*. On p. 253 of the memoir, Mr. Lamplugh quotes a specimen of *Posidonomya Becheri* in the Cumming collection as having an ashy matrix, and states that Mr. J. A. Howe obtained a specimen of *Glyphioceras striatum* in the ash beds. The species is nearly always associated with *Posidonomya Becheri* at the base of the Pendleside series in Yorkshire. It is therefore very probable that the ash or part of it was of Lower Pendleside age, and in connection with this it is interesting to note that the ash beds in the old quarry near Astbury, Cheshire, and in Tissington railway cutting, Derbyshire, occur at the same horizon, i.e., at the junction of the upper part of the Carboniferous Limestone with the Pendleside series.

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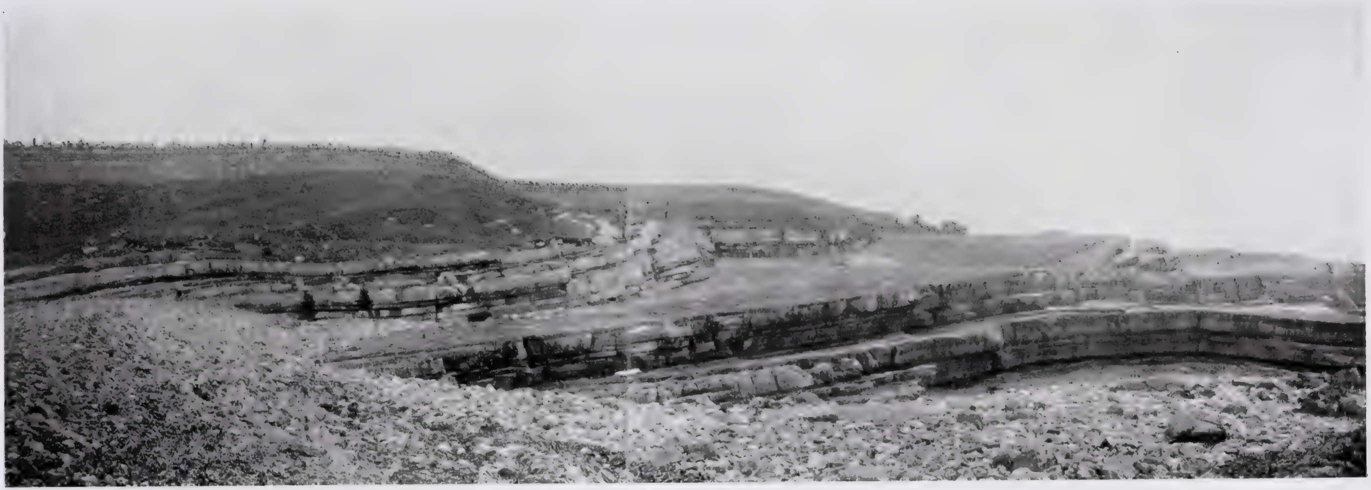
*Proc. Roy. Irish Acad., vol. xxv., sec. B, No. 4, pp. 93-116.

† Rep. Brit. Ass., 1902.

‡ Q. J. Geol. Soc., vol. lvii., pp. 307-402.

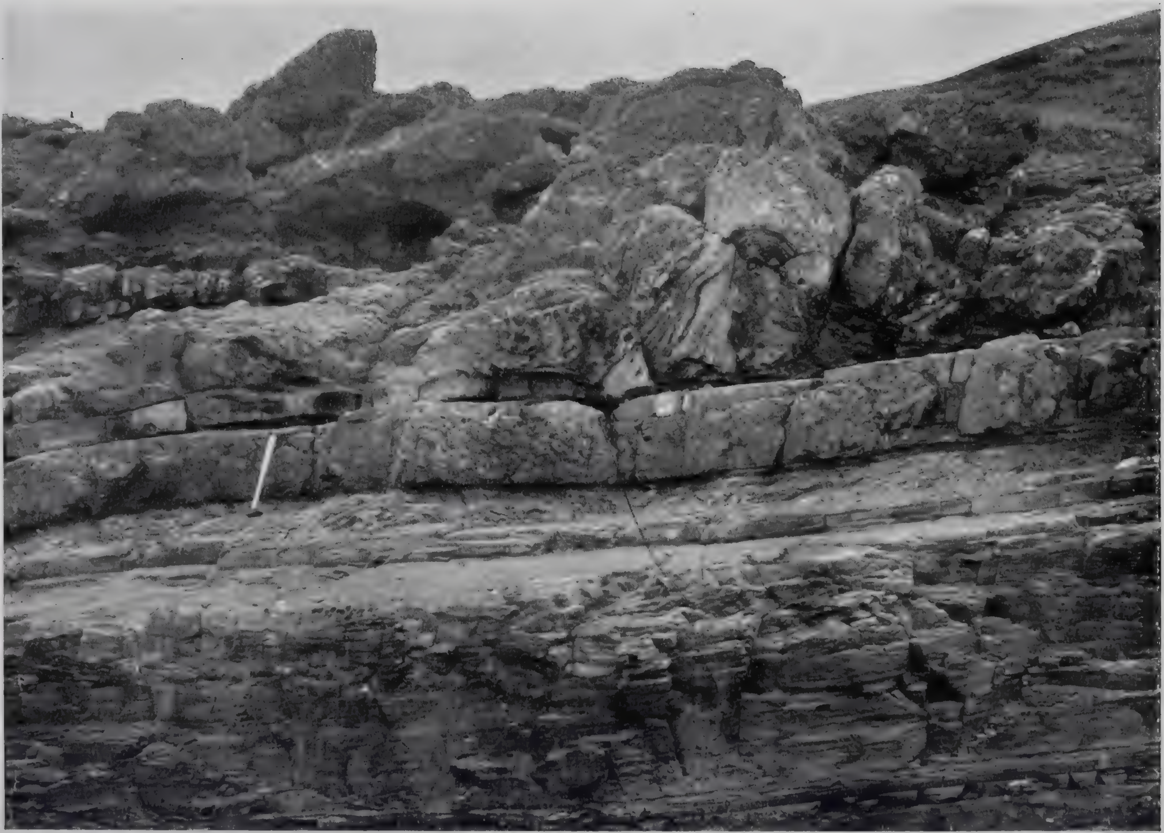
§ Geol. Mag. Dec. 5, vol. i., pp. 392-403.



Photographed by Godfrey Bingley, Headingley, Leeds.

UNDULATIONS IN LIMESTONE, SCARLET POINT.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XV.



Photographed by Godfrey Bingley, Headingley, Leeds.

OVERTHRUST IN BEDDED VOLCANIC ASH, CLOSE NY CHOLLAGH POINT.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XVI.

The following flora and fauna have been obtained from the black or *Posidonomya Becheri* shales of Poolvash :—

Posidonomya Becheri.
Pterinopecten papyraceus.
Solenomya costellata.
Glyphioceras striatum.
Nomismoceras rotiforme.
Orthoceras Koninckianum.
  ,, *Morrisianum.*
Small Zaphrentid corals (new; also occurring in the ash, *fide* Sibly).
Callograptus Monensis.

Plantæ—
Adiantites antiquus.
  ,, *Machaneki.*
Sphenopteris pachyrachis.
  ,, ,, var. *stenophylla.*

THE LIMESTONES OF SCARLET.

Plates XV. and XVI.

The limestones of Scarlet were relegated by both Cumming and Lamplugh to the Lower or Castletown Limestones.

As seen at Scarlet and on the foreshore between Castletown and Scarlet, they consist of dark blue, well-bedded limestones, becoming cherty in places. The beds are well marked and have shale partings.

On the foreshore immediately below the quarry is a bed of limestone crammed with large Caninoid Campophyllids, *Lithostrotion* cf. *irregulare*, and other corals.

In addition to these, the typical corals of the quarry are:

Zaphrentis Enniskilleni. Very common.
  ,, Sp. nov.
Amplexizaphrentis.
Cyathaxonia costata.
Cyathophyllum Murchisoni.
Densiphyllum Sp.
Koninckophyllum Sp. nov.

Amplexus Sp. nov.
Cyclophyllum cf. *Wunschii.*
Caninoid *Campophyllum.*
Lithostrotion affine.
,, cf. *irregulare.*

The following fossils also occur:

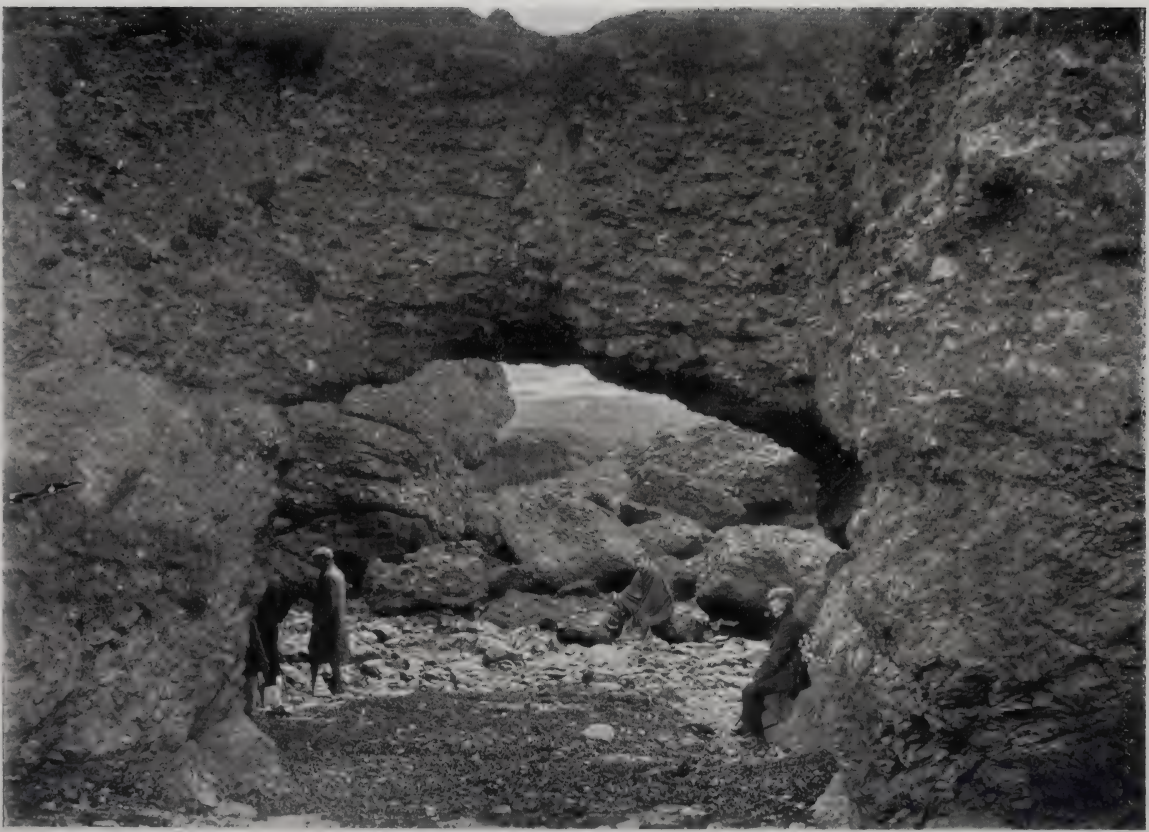
Trilobites—
- *Phillipsia Polleni.*

Brachiopoda—
- *Productus longispinus.*
  - ,, *fimbriatus.*
  - ,, cf. *corugatus.*
  - N.B.—*Productus giganteus* is quoted on the authority of Geological Survey, Cummings, and Davidson.
- *Spirifer pinguis.*
  - ,, *planicostata.*
  - ,, *striatus.*
  - ,, *ovalis.*
- *Martinia glabra.*
- *Strophomena analoga.*

Lamellibranchs—
- *Allorisma Monensis.*
- *Edmondia sulcata.*

Cephalopoda—
- *Prolecanites compressus.* In upper beds. Fairly common.
- *Pleuronautilus Scarletensis.*
- *Solenocheilus dorsalis.*
  - ,, *pentagonus.*
- *Discitoceras Leveillianum.*
- *Temnocheilus Cricki.*
- *Poterioceras cordiforme.*
- *Orthoceras* sp. Very large.

This fauna has a very high facies, and the coral fauna corresponds with that which characterises the upper part of the limestone of Derbyshire and N. Wales. Mr. Sibly, who kindly examined the corals for me and visited the sections



Photographed by Godfrey Bingley, Headingley, Leeds.

BASEMENT CARBONIFEROUS CONGLOMERATE RESTING UNCONFORMABLY ON MANX SLATES, LANGNESS.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XVII.

with me on the occasion of the excursion of the Yorkshire Geological Society, tells me that the new forms noted from Scarlet are found in the beds immediately below the *Posidonomya Becheri* beds in the Midlands.

Mr. Stobbs and I in our paper on the Carboniferous succession below the coal measures in North Shropshire, Denbighshire, and Flintshire* point out that the coral genus *Cyathaxonia* denotes a sub-zone at the top of the Upper *Dibunophyllum* zone. The facies of the whole fauna is a very high one, and the occurrence of *Prolecanites compressus* indicates the passage beds or very base of the Pendleside series.

The rocks which are exposed on both sides of Castletown Harbour are characterised by a very similar fauna to that which obtains at Scarlet, and evidently belong to the same series.

THE LIMESTONES OF DERBYHAVEN, RONALDSWAY, AND LANGNESS.

The striking fact of the Carboniferous succession at Derbyhaven (Cass ny Hawin) and Langness is that the lowest beds of the series rest on the basement conglomerate, and consequently give a definite, if local, base to the series. This conglomerate contains no contemporary fossils, and lies on the upturned edges of the Manx slates (Plate XVII.). On it lie the well-bedded, gently dipping limestones of Derbyhaven and Langness. Mr. Lamplugh estimates the thickness of the limestones of Derbyhaven and Ronaldsway at 189 ft. Each bed appears consecutively on the foreshore, and can be examined and searched for fossils, but as there is no quarrying, doubtless the fauna as shown in the following list is much too meagre.

I carefully collected from each bed from Cass ny Hawin to the breakwater at Ronaldsway. The lowest fossiliferous bed I found was about 20 ft. from the base of the series, and it contained :

Cyathophyllum cf. ϕ.
Syringopora distans.
Lithostrotion Martini.
Chonetes papillionacea.

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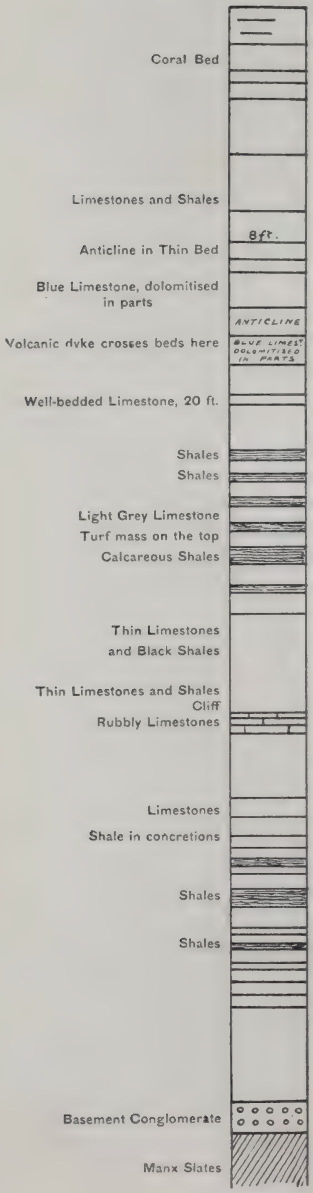
* Geol. Mag. n. s., dec. 5, vol. iii., p. 500.

My other results are expressed in the following table:—

SECTION FROM CASS NY HAWIN TO RONALDSWAY.



Chonetes, cf. Comoides (gigantean form).

Lithostrotion affine, Zaphrentis Enniskilleni, Cyathophyllum cf. ϕ, Michelinea megastoma, Syringothyris cuspidata, Chonetes cf. laguessiana, Orthotetes (larger form). Spirifer glaber, Reticularia lineata, Productus punctatus, P. concinnus.

P. cora, Conocardium alæforme, Bellerophon, Archæocidaris, Palæchinus.

Bellerophon sp.

Orthotetes, Cyathophyllum cf. ϕ and stalks of ? fucoids.

Fucoid stalks.

Crinoids.

Syringopora, Cyathophyllum aff. ϕ at top.

Euomphalus.

Fenestella, Bryozoa, Cyathophyllum cf. ϕ, Productus concinnus.

Michelinea megastoma, Zaphrentis Enniskilleni.

Michelinea megastoma, Chonetes (small sp.), Zaphrentis Enniskilleni, Lithostrotion Martini, Spiriferina.

Productus pustulosus, P. punctatus, Orthotetes, Schizoptoria Michelini, Bryozoa, Syringothyris cuspidata.

Diphyphyllid Cyathophyllum, Cyathophyllum Murchisoni.

Caninoid Campophyllum, Amplexus coralloides, Zaphrentis Enniskilleni, Diphyphyllum subibicina McCoy, Productus punctatus, Schizoptoria Michelini, Bellerophon sp.

Michelinea megastoma.

Fucoid stalks.

Cyathophyllum cf. ϕ, Zaphrentis Enniskilleni.
Fucoids.

Bellerophon.

Palæchinus, large tuberculate plate, Bellerophon, Crinoids.

Naticopsis, Cyathophyllum cf. ϕ.
Crinoids.

Crinoids, Orthotetes crinistria, Syringopora, Spiriier sp. with angular ribs.
Bellerophon, Productus Martini.
Syringopora, Cyathophyllum aff. ϕ, Lithostrotion Martini, Chonetes papillionacea, Palæchinus.

The section exposed from Langness to Castletown Harbour is more difficult to collect from.

There is a basement conglomerate resting on Manx slates, which is apparently the same rock as that seen near Cass ny Hawin, and this is overlaid by well-bedded limestones, the lower of which are much obscured by an overgrowth of seaweed, as they form the foreshore between high and low water marks. About 20 ft. from the base of the limestone occurs the caninoid *Campophyllum* with *Productus hemisphericus*, *Chonetes papillionacea*, *Spirifer* cf. *bisulcatus*.

The limestones are not well exposed between Langness and Castletown Harbour, but at the latter place about 30 ft. of beds are seen which contain—

Caninoid *Campophyllum.*
Prolecanites compressus.
Orthoceras (*Actinoceras*).
Leptæna analoga.
Giganteid *Producti.*

The fairly broad gap between the Langness beds and those of Castletown Harbour is evidently of no great vertical extent, for the fauna on each side is characterised by the same caninoid *Campophyllum*, which indicates that both series belong to one and the same life zone.

If the list of fossils from the Castletown Limestones given in the memoir, pp. 257-262, be consulted, a long list of species is quoted on the authority of several observers from the Lower or Castletown Limestones.

If the identifications contained in this list be any way nearly correct, the fauna, as a whole, has a markedly high facies *Martinia* (*Spirifer*) *glabra*, *Spirifer ovalis* and *Productus giganteus* would definitely denote *Dibunophyllum* zones.

In the collection made by Miss Burleigh, now in the Natural History Museum, South Kensington, are several specimens of *Spirifer ovalis*, labelled Scarlet quarry.

There are several exposures of the Lower or Castletown Limestones in a series of extensive quarries near Ballasalla, in which practically the same series is worked in each exposure. I estimated roughly the limestones exposed at 50 ft.

Here I obtained :—

Zaphrentis Enniskilleni. Very abundant.
Michelinea megastoma.
Caninoid *Campophyllum.*
Lithostrotion Martini.
Euomphalus sp.
Straparollus sp.
Bellerophon sp.
Naticopsis sp.
Productus punctatus.
,, *corrugatus.*
Syringothyris cuspidata.
Spirifer sp.
Chonetes. Small, finely ribbed species.
,, *papillionacea.*
Edmondia sulcata.
Allorisma Monensis.
Sanguinolites plicatus.

North-west of Poolvash, at Strandhall, well-bedded limestones appear on the foreshore. These beds are very rich in fossils and contain *Productus giganteus* in abundance, with *Chonetes papillionacea* and the following corals :—

Caninoid *Campophyllum.*
Cyclophyllum pachyendothecum.
Clisiophyllids.
Cyathophyllum cf. *Murchisoni.*
Zaphrentis Enniskilleni.
Lithostrotion affine.
,, *Martini.*
Syringopora geniculata.
,, *ramulosa.*

The coral fauna identifies the beds as belonging to the same series as Scarlet, but the striking feature is the abundance of *Productus giganteus*, ràre in the other sections.

THE LIMESTONES OF PORT ST. MARY.

On p. 196 of the Memoir, Mr. Lamplugh shows that the basement conglomerate occurs at Port St. Mary, having been found below low water. This fact indicates that the limestones are those which succeed the basement conglomerate. Mr. Lamplugh, p. 205, *op. supra cit.*, estimates that there are 81 ft. of limestone exposed at Port St. Mary. He notes that corals are abundant. The coral fauna is identical with that of the lower part of the Scarlet Limestones, and I obtained at Port St. Mary:—

Zaphrentis Enniskilleni.
Caninoid *Campophyllum.*
Cyathophyllum sp.
Lithostrotion affine.
,, *Martini.*
Syringopora sp.

Unfortunately time prevented me from collecting here as much as in other sections, but the coral fauna shows that the series is the equivalent of part of the Derbyhaven sequence.

CORRELATION OF THE LIMESTONES.

The faunas from all the sections demonstrate that the whole of the limestones described by previous authors as the Lower Limestones belong to one and the same series, which, at most, can be only 200 ft. thick. The coral fauna of Scarlet shows that the beds belong to the upper part of the *Dibunophyllum* zone of the Bristol area, and pass up without a break, both at Scarlet and the black limestone quarry of Poolvash, into the *Posidonomya Becheri* beds of the Pendleside series. Portion of the series, the *Cyathaxonia* beds, represents a slightly higher phase than occurs at Bristol, which is found well developed in North Wales and in certain localities in North Staffordshire and Derbyshire, in the cherty limestone series of Warslow, near Waterhouses, and at Bradbourne.

The Poolvash Limestones.

So far the succession is free from difficulty and easily demonstrated, but the white shelly limestones of Poolvash present some curious problems, which must be dealt with now in detail.

Mr. Lamplugh has given a very full and lucid account of the stratigraphical side of this question, pp. 208-216, and to this I can add practically nothing.

The Poolvash Limestones have long been known as good collecting grounds for fossils, and they occupy about half-a-square mile between the Balladoole fault and the out-crop of the volcanic series at Poolvash. At the latter place these limestones, which exist as dome-shaped masses, can be seen to pass under the black shales of the *Posidonomya* beds. Lamplugh says, p. 216: "The most southerly exposure of the limestone bosses on the coast occurs just above high water mark on the southern side of Poolvash inlet. . . . The *Posidonomya* or black marble beds then completely overlap them to the westward and southward, occupying a little strip on the upper part of the shore, while the lower part is composed of the overlying volcanic ash, &c."

The Poolvash Limestones occur in knolls, or detached masses, without any definite bedding planes. The knolls are of various sizes, some being diminutive, and when unaltered by metasomatic changes are crowded with fossils.

The fossils belong chiefly to the Mollusca and Brachiopoda. Corals are rare, but Dibunophyllids and *Lithostrotion Portlocki*, and *Lonsdaleia floriformis* occur.

The Mollusca are represented by many Cephalopods, Lamellibranchs, and Gasteropods, all jumbled up together, the larger shells filled with smaller forms. The Cephalopoda in many cases possess their body chambers, and the bivalves often have the two valves in contact, but the valves have nearly always slipped, and many are single, indicating an entombment after the death of the animal. None of the shells seems to be rolled, but it seems impossible to suppose that all the forms found together could have been adapted to the same environment. The Brachiopoda are generally perfectly preserved, and the valves are in contact, and those with spiral internal arrangements have them preserved. I have come to the conclusion that these facts indicate an original shell bank, which was subsequently covered up by the shales and dark limestones of the Pendleside series.

This condition of things at Poolvash is by no means unique. Similar knoll-like shell beds occur at Park Hill, Thorpe Cloud, Narrowdale, Wetton, Castleton, Clitheroe, Withgill, and the Cracoe Fells, in all of which is found identically the same fauna that characterises the Poolvash Limestone. The general characters of these shell beds are very similar. They are composed of White Limestone, from which the shells are easily cracked out. All sorts of Mollusca, Brachiopoda, and fish teeth are jumbled up together, rendering the bedding planes very indistinct. These shell beds appear to occur at, or nearly at, the top of the Limestone Series, and to lie in all cases immediately below the *Posidonomya Becheri* beds.

The relation of these shell beds to the *Cyathaxonia* beds is obscure, and generally where the one is present the other seems to be absent in the passage from the limestone series to the shales, though owing to the very local character of the shell beds, these two terms in the Upper *Dibunophyllum* zone may be not very far apart. For example, at Elbolton, Hill Stebden, and Keal Hill, of the Cracoe Fells, the shell beds are apparently succeeded by shales of the Pendleside series. At Butterhaw and Hill Skelterton there is a passage up from well-bedded limestones with many stools of *Lithostrotion* and other corals through *Cyathaxonia* beds to the *Posidonomya Becheri* beds.

The shell beds are characterised by the presence of *Reticularia lineata*, *Martinia glabra*, *Spirifer ovalis*, *S. planicosta*, *Schizophoria resupinata*, and many other Brachiopods typical of a high fauna. They are also all characterised by abundance of *Glyphioceras crenistria*, *G. truncatum*, and *G. obtusum*, amongst other Cephalopods. At any rate, then, the Poolvash Limestone and fauna are well known, and have been studied in many localities on the Mainland. Various elaborate theories have been formulated from time to time to explain the peculiar knoll-like character of the shelly limestones, which I need not discuss here. As I mentioned above, corals are not common in the shell beds, but I have obtained specimens of Dibunophyllids, *Lonsdaleia floriformis*, *Lithostrotion Portlocki*, and other species, all of which indicate the Upper *Dibunophyllum* zone. Indeed, the Brachiopod fauna alone emphatically indicates this horizon to be of Upper *Dibunophyllum* age.

It is probable, then, that the Poolvash shell-beds are of the same age as a part of the Castletown Limestones. They may be somewhat older, but they can scarcely be newer. They are certainly older than the upper part of the Scarlet beds with *Cyathaxonia*. It will, therefore, be inadvisable to call the Castletown Limestones "lower" in future in relation to the Poolvash Series.

The section given by Mr. Lamplugh on p. 54, *op. supra cit.*, is interesting and important.

The upper part consists of massive Pale Limestone, with bedding obscure and fossils abundant. Beneath are dark flaggy limestones with shaley partings, also fossiliferous, resting on a limestone breccia.

The upper beds have the rich Brachiopod fauna mentioned above; those below are full of corals, Dibunophyllids, *Lithostrotion* cf. *Portlocki*, *Clisiophyllum*, *Cyathophyllum* cf. *Murchisoni*. Beds immediately below the section contain *Productus giganteus*, caninoid *Campophyllum*, and other corals.

The curious fact remains that both the Castletown Limestones at Scarlet, and the white shelly limestones at Poolvash are succeeded by the dark limestones of the Pendleside series i.e., the *Posidonomya* beds.

The Limestones both of Castletown and of Poolvash, then, clearly belong to the Upper *Dibunophyllum* zone, the subzone of *Cyathaxonia* being also represented and being succeeded by black limestones and shales of the Pendleside series.

It is only reasonable to infer, seeing the Scarlet, Ballasalla, Castletown, Langness, and Derbyhaven beds contain the same *Zaphrentis* and caninoid *Campophyllum*, that they are all of one age. But the pros and cons of this important question are discussed more fully below.

In our paper on the Carboniferous Succession below the coal measures in North Shropshire, Denbighshire, and Flintshire, *op. supra cit.*, Mr. Stobbs and I showed that the Lower Carboniferous rocks of the Bristol succession were not deposited in that area, and that the land only sank beneath the sea in late *Seminula* times. Mr. Cosmo Johns (Geol. Mag., Dec. 5, vol. iii., 1906, p. 320) showed that the horizon of the basement beds at Ingleboro' was probably that of the lowest *Seminula* times. It now appears that the Manx slates remained above water, probably as the shoulder of a mountain whose summits never sank below the Carboniferous sea, showing how long insular conditions have existed even for so small an area as Manxland. It is probable, however, that a much greater thickness of Carboniferous rocks may surround the island beyond its present shore-line, or even form part of it buried beneath the glacial deposits which form the lowlands of its northern portion.

GENERAL CONCLUSIONS.

During the last two or three years much research has been going on in various Carboniferous areas and I learned much from my work on the sequence in North Wales, in conjunction with Mr. J. T. Stobbs. The sequence there showed that there were two series of black limestones, one that of Teilia, characterised by *Posidonomya Becheri*, *Pterinopecten papyraceus*, and a goniatite fauna, the other, the black limestones of Prestatyn, characterised by *Zaphrentis Enniskilleni*, and that the latter formed part of the Upper *Dibunophyllum* zone. I had previously obtained *Z. Enniskilleni* from the black marble of Ashford, Derbyshire, and from beds at Whitewell and Swinden Gill, Yorkshire, which were apparently just below the base of the Pendleside series. Also in the county of Limerick at the same horizon, immediately below the Pendleside series of Foynes Island.

In Swinden Gill the beds with *Z. Enniskilleni* overlie massive limestones in which a caninoid *Campophyllum* is very common.

Both in Yorkshire, as at the Craven knolls, and in North Wales, at Axton and near Meliden, highly fossiliferous, knoll-like beds of white limestone occur, containing a similar fauna to the Poolvash shell beds. Their relation to the *Zaphrentis Enniskilleni* beds or well-bedded coralline limestones is obscure, and they seem to in some way replace them; but wherever *Zaphrentis Enniskilleni* comes on, the *Posidonomya Becheri* beds may be expected to succeed them in each case.

This fossil appears to characterise all the well-bedded limestones of the Isle of Man, but it is absent in the white limestones of Poolvash. Nor does it appear to have a very wide vertical range.

In the Yorkshire area it first appears in black shales overlying the Hardraw Scar Limestone, with a typical Upper *Dibunophyllum* fauna. I believe it has never yet been found in the Bristol area, but I have found it, or a very close relative, in the black limestone of Oystermouth Castle, in the Gower peninsula, associated with trilobites and other members of the Upper *Dibunophyllum* zone.

Hence I rely locally on this fossil to give a definite index for the correlation of the various outliers or isolated exposures of the well-bedded limestones of the south of the Isle of Man.

The Derbyhaven beds have given me much food for thought. The fauna there contains corals which are generally considered to have a low facies, for example, *Michelinia megastoma*, and the view is somewhat strengthened by the presence of a large *Chonetes*, of a *Chonetes comoides* character, but with a much thicker shell than the *C. comoides* of the Bristol-Mendip area. But *Zaphrentis Enniskilleni*, on the other hand, always denotes a high horizon in the *Dibunophyllum* zone, and this is very abundant in the Derbyhaven-Ronaldsway sequence. There can be no doubt of the *Dibunophyllum* age of the sequence at Scarlet, which contains *Cyclophyllum*, *Cyathaxonia*, and *Z. Enniskilleni* as well as the Campophyllid corals. At Derbyhaven some of these corals are associated with *Michelinia megastoma*, which is supposed in other areas to indicate a low zone. I have not yet found this coral myself at Scarlet, but a specimen closely allied is to be seen in the breccia bed between the black shales and a small limestone knoll at Poolvash.

Insular condition, which I have alluded to above, may be the cause of this faunal peculiarity. Migration may have occurred too late, or been unfavourable to certain forms of life, or bathymetrical conditions, or environment may have prevented the establishment of organisms which flourished luxuriantly elsewhere at the same time.

At any rate, I have done what is possible with the fauna as we know it to-day. Further researches may bring to light fossils which will give more definite evidence for the purposes of correlation. I have collected in all localities myself and have endeavoured to see all public and private collections made from the localities, but unfortunately the rich character of the Poolvash Limestone has drawn collectors to that locality, and the less productive limestones of Derbyhaven, Langness, and and Ballasalla have not been searched as thoroughly as they might have been.

As the title of the paper shows, I did not propose to deal in any way with the buried Carboniferous rocks of the northern area. These rocks have only been reached by borings, and fossil evidence is at present insufficient to form any views whatever as to what part of the Carboniferous series occurs there.

On page 288 Mr. Lamplugh quotes the presence of *Productus longispinus*, as determined by Messrs. Sharman and Newton. This species is not known below the Upper *Dibunophyllum* zone. No borings are deep enough, however, to give any indication of the thickness of limestones present.

With regard to the Peel Sandstones, which I saw with Mr. Lamplugh, I can only say that I know of no rocks of Carboniferous age which in any way resemble them, and the absence of any definite Carboniferous fossils, though some of the calcareous beds are fairly fossiliferous, makes it very unsafe to assume that they belong to that age at all. I am aware that

Professor Boyd Dawkins, who believes the rocks to be of Permian age, states on the authority of Mr. E. T. Newton, that *Griffithides glaber* and *Chonetes Laguessiana* occur in pebbles in the Peel Sandstones, but the majority of fossils found are of Keisley Limestone age.*

I have to thank Dr. A. Vaughan and Mr. T. F. Sibly for kindly determining corals collected at the various quarries and exposures in the Island, and congratulate myself that I was fortunate enough to have the company of Mr. Sibly over the ground on the occasion of the visit of the Yorkshire Geological Society. His views are the more valuable because I have long had correspondence with him and Dr. Vaughan both on the zonal value and inferences to be drawn from the fauna.

To my friend Mr. Lamplugh I must give my heartiest thanks for valuable suggestions and criticisms, and for reading the proofs while the paper was passing through the press.

To Mr. Godfrey Bingley I owe my best thanks for the beautiful photographs which illustrate this paper and the note on Carboniferous Graptolites in this volume.

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* Q. J. Geol. Soc., vol. 58, pp. 633-661.

ON THE OCCURRENCE OF DENDROID GRAPTOLITES IN BRITISH CARBONIFEROUS ROCKS.

BY WHEELTON HIND, M.D., B.S., F.R.C.S., F.G.S.

When collecting in the Pendleside series of Pendle Hill for the British Association Committee on Life Zones in the British Carboniferous Rocks, Mr. D. Tate, collector on the staff of the Geological Survey of Scotland, found a curious specimen in the shaly limestones in Hook Clough. He sent it to me with a note that he believed that he had discovered *Dictyonema* in Carboniferous rocks. The specimen was sent to various specialists. Mr. R. Kidston expressed his opinion that the fossil belonged to *Dictyonema*, a view with which I agreed. Subsequently Mr. Tate, while collecting for the same Committee in beds of presumably the same horizon at Poolvash, Isle of Man, discovered a specimen of a similar organism in the black shales with *Posidonomya Becheri*. This specimen was evidently specifically distinct from the one found on Pendle Hill. I wrote a short description of the two forms, under the modest title of " Note on Some Dictyonema-like Organisms from the Pendleside Series of Pendle Hill and Poolvash," and it was read at the Geological Society on March 25th, 1903. The Society, with that caution which characterises the Publication Committee when new matters are brought before the Society, decided not to publish the note. Subsequently I asked Miss G. Elles to examine the fossils, and she wrote :—" I think the specimens from Poolvash and Pendle Hill are Dendroid Graptolites without a doubt. The Poolvash specimen looks like a *Desnograptus*, and the other is a *Callograptus*, I think. The *Desnograptus* is more spread out than in other specimens known to me and is probably new, but the *Callograptus* has some very near allies in *C. Salteri* and *C. radiatus* of the older rocks. The presence of the joining bar has generally been regarded as distinctive of the genus *Dictyonema*, but my experience leads me to believe that this is not the case. 'Bars' may be present in all the Dendroids, I think, but they are particularly regularly developed in *Dictyonema* itself. The fashion of growth is a far more distinctive and reliable character."

Lately I had the opportunity of showing the specimens to Dr. H. Lapworth, F.G.S., and he unhesitatingly pronounced them to be Dendroid Graptolites.

Under these circumstances I think the figures and brief descriptions of the specimens should be published.

CALLOGRAPTUS CARBONIFERUS, sp. nov. Fig. 1, Pl. XVIII.

Specific characters.—Frond branching from a single acute base, obscurely fan-shaped. Branches narrow and linear, dividing dichotomously, united by occasional dissepiments, forming a retiform network, with large elongate meshes.

Locality.—Pendleside series, Hook Clough, 60-70 yards up stream from the old road at the back of Hook Cliff farm house.

Observations.—The fauna associated with this Graptolite was:—

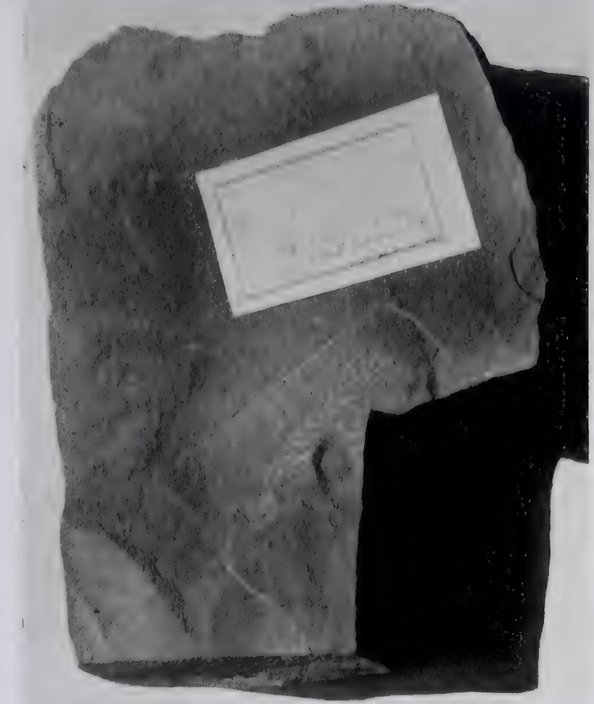
Prolecanites compressus.
Stroboceras sulcatus.
Solenomya costellatus.
Ceratiocaris, sp.
Productus cf. *semireticulatus.*

DESNOGRAPTUS MONENSIS, sp. nov. Fig. 2, Pl. XVIII.

Specific characters.—Frond narrow and elongate. Branches dividing dichotomously, joined by few transverse dissepiments, forming a small open diamond-shaped network.

Locality.—Pendleside series, Poolvash, Isle of Man, from black shale interbedded with lenticles and hummocks of limestone, containing marine fossils, in the first hollow between tide marks, west of the barn at Poolvash farm.

Observations.—The network is more regular and meshes not so elongate, nor is the frond as fan-shaped as is the case with *Callograptus carboniferus.*



Photographed by Godfrey Bingley, Headingley, Leeds.

Fig. 1.

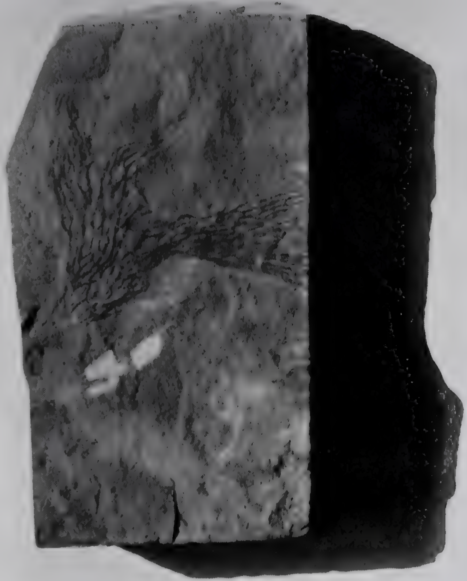


Fig. 2.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XVIII.

The following fossils occur with *D. Monensis*:—

Adiantites Machaneki.
,, *antiquus.*
Sphenopteris pachyrachis.
,, allied to *S. bifida.*
Posidonomya Becheri.
Pterinopecten papyraceus.
Solenomya costellata.
Orthoceras Morrisianum.
,, *Koninckianum.*
Glyphioceras reticulatum.

THE STRUCTURE OF SOME CRAVEN LIMESTONES.

PART II.

ON THE STRUCTURE AND ORIGIN OF THE CRAVEN LIMESTONE KNOLLS.

BY A. WILMORE, B.SC., F.G.S.

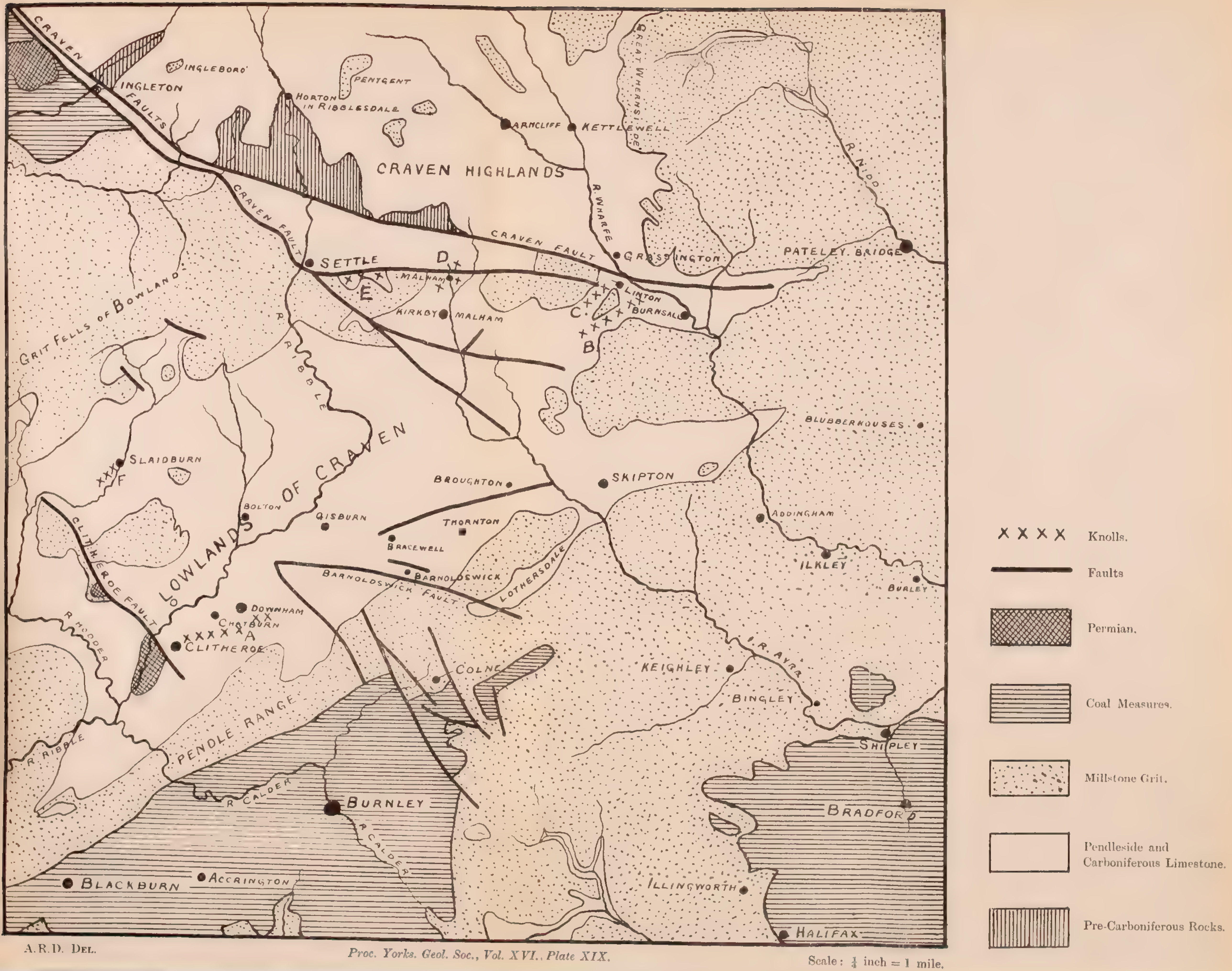
Read at the Meeting held at Colne, March 29*th*, 1907.)

There are in certain parts of Craven a number of knolls of limestone which are somewhat conical, or dome-shaped, and which are mainly or wholly composed of greyish-white or bluish-grey limestone, and are often, but not always, very fossiliferous.

These knolls have been the source of some contention, and a number of papers have been written dealing, more or less directly, with observations on the nature of, and theories concerning the origin of these structures (see bibliography, p. 169).

The knolls occur in certain well-defined areas, more or less linear sets, of apparently a common type, being seen in the following districts :—(*a*) Downham, Chatburn, and Clitheroe ; (*b*) Cracoe, Thorpe, and Burnsall, close to the grit fells ; (*c*) near Rylstone and Grassington ; (*d*) Malham ; (*e*) Stockdale and Scaleber, east of Settle ; (*f*) Slaidburn district. There are isolated or detached masses, which have some of the characteristics of the knolls, (*g*) on the Greenhow extension of the Cracoe fold, (*h*) at Fogga, near Hellifield, (*i*), at Newsholme, near Gisburn.

It is obvious that the distribution of these knolls is intimately associated with the well-known directions of disturbance in the district. The key to the structure of the district is furnished by the Craven Faults and the associated folds to the south and south-west of them (see Plate XIX, to which the above letters refer).



A.R.D. Del.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XIX.

Scale: ¼ inch = 1 mile.

It will be necessary to recall the chief features of the physical geography of the district.

First we have the Craven Highlands, to the north of the inner fault, the country of the dales proper and the land of the famous scars. Here the strata are almost horizontal, the Carboniferous Limestone series being succeeded by the Shales with Limestone and then by the Millstone Grit which forms the summits of Penyghent, Ingleborough, and Fountains Fell. Dr. Wheelton Hind informs me that he has recently proved the existence of the Pendleside fauna in the southern part of the Highland area to the north of Malham, but I do not know of anything corresponding to the knolls of Lower Craven in this area. The limestones are sometimes quite as irregularly bedded, and there is the same variation in fossiliferous character, but the rounded detached hills do not occur.

The Northern Branch of the Craven Faults runs from Ingleton, north of Malham, to the neighbourhood of Pateley Bridge. The middle branch runs from Ingleton to Malham and on to Winterburn. The southern "branch" is a complex system branching off near Settle, and running south to the neighbourhood of Skipton.

The faults at Barnoldswick, at Twiston (near Downham), and the limestone boundary fault at Clitheroe, as well as the north-eastern boundary fault of the Burnley Coalfield, are somewhat similar in direction to the Craven Faults (Plate XIX).

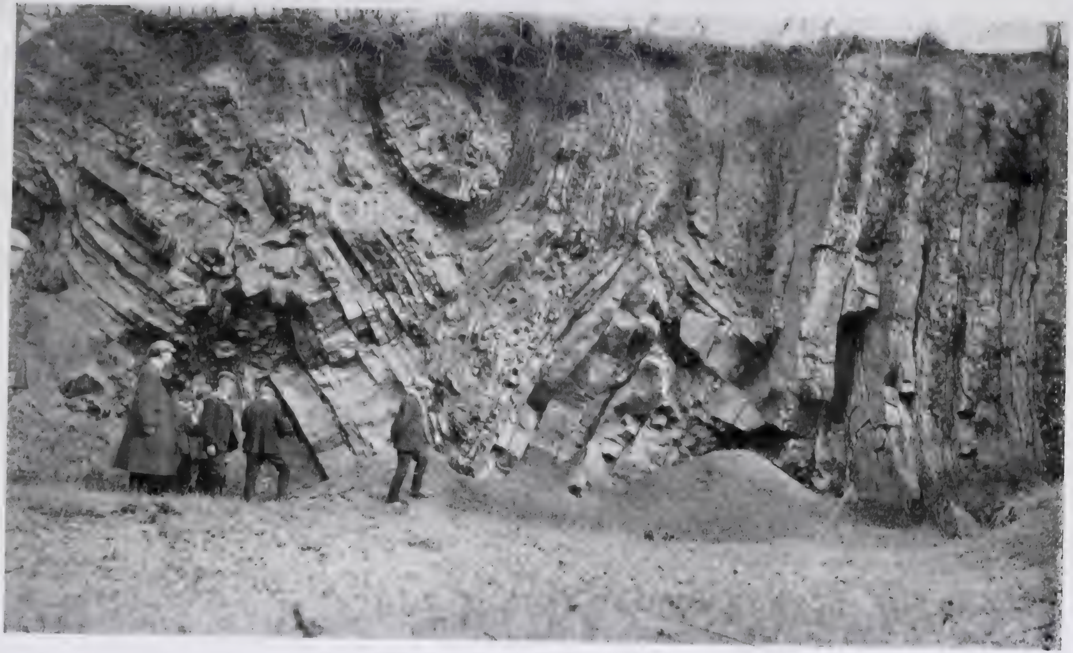
It has often been pointed out that the throw of the Craven Faults decreases as they are traced eastwards, and becomes comparatively small in the knoll district (see especially Hind and Howe, Q.J.G.S., lvii.). Is it not difficult to conceive of a very great difference in the succession of the beds or a radical change in the fauna north and south of the faults, when the throw is so small? Are not any observed differences rather to be attributed to a gradual change in the succession and in the fauna as the beds are traced from south to north independently of the faults themselves? The succession in the country between the northern and middle branches of the Craven Faults is not very different from the succession further south.

Secondly, we have the rolling country of Lowland Craven, where the rocks are folded. The strata are mainly shales and limestones, with apparently a very variable lithological sequence in different parts of the district. There are well-marked anticlinals, the one which strikes S.W. to N.E. from Clitheroe to Grassington being the most important. There are minor folds striking nearly at right angles to these, seen in the Marton and Gargrave district. Almost every exposure—and they are very numerous—shows some signs of intense folding or faulting. Naturally the thin-bedded muddy limestones show the folding best, but it is also seen in the more massive and unevenly bedded grey limestone. It is almost exclusively on the borders of this region of folding that the grey fossiliferous knolls occur, and there are knolls in the most perfectly bedded blue Limestones with Shales, which occupy exactly corresponding positions, and which are as nearly like them as their different lithology will admit.

The faults and folds are obviously closely connected, because the latter end off sharply against the former, and it is difficult to resist the conclusion that they are due to the same series of movements. An illustration of the folding is given in Plate XX.

Thirdly, there is the region of grit moorlands of Todmorden and Hebden Bridge, to the south-east of the coalfield of Burnley. Here we have a foreland of the Craven folded system. The grits lie nearly horizontally, and the hills become tabular masses, thus reproducing some of the features of the country north of the Craven Faults. Just as these faults separate the tabular Craven Highlands from the folded Craven Lowlands, so there is a series of faults—not nearly so complete or so well seen—separating the lowlands from the foreland of grit hills.

The hills of the eastern part of the Pendle Range are of the nature of escarpments, on the flanks of shallow synclinals at the edge of the folded country, while those in the western



Photographed by Joseph Lomas, Liverpool.

SECTION IN CARBONIFEROUS LIMESTONE, FOXLEY BANK.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XX.

part consist of the middle limb of an anticlinal fold. The relation of the eastern hills to the folded country is shown in the diagrammatic section, Fig. 1.

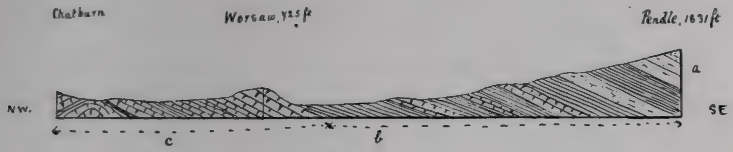


Fig 1.

SECTION FROM PENDLE TO CHATBURN THROUGH WORSAW KNOLL.

a. Base of Millstone Grit Series. Pendle (? Farey's) Grit.

b. Pendleside Series, Shales with variable limestones and grits.

c. Carboniferous Limestone Series, with coarse, massive "Knoll" Limestone at the top.

Referring again to the diagram map, Plate XIX, it will be seen that the distribution of the knolls is intimately related to the structure of the country, as briefly outlined above.

It seems clear that the knolls depend *more* upon the "tectonics" of the district than upon any peculiarities of deposition, though I do not deny that such peculiarities may have existed, and may have had something to do with the development of the knolls.

I propose in this paper to study rather more intimately the remarkable series of knolls in the Downham-Clitheroe district. These are marked (A) on Plate XIX. There are five at least of these knolls forming a well-marked series, namely, the hills of Twiston, Sykes, Gerna, Worsaw, and Worston, though I do not see why the low hill of Bellman Quarry, Salt Hill, and Clitheroe Castle Hill should not be included. They do not form the same "ovoid eminencies," but the limestone itself, the bedding, the fossils, the secondary deposits of stalagmite, fluor, pyrites, and limonite pseudomorphs after pyrites, are precisely similar. Omitting the Castle Hill, which I have not been able to study very fully, and beginning at the Clitheroe end of the series, the following is a brief description of the knolls. (See one-inch Geol. Map, 92, S.W., new series, sheet 68.)

(*a*) Salt Hill. This is a low rounded hill, now partly removed by quarrying. The limestone is for the most part a well-bedded greyish-white crinoidal debris, containing broken and rolled shells. The stems and plates of crinoids and the shells weather out from the massive limestone on long exposure. There is abundant iron oxide in parts, and the limestone sometimes weathers to a clay of a brownish-yellow colour. There are layers of light blue very fine-grained limestone, with occasional megascopic fossils in excellent preservation. This quarry has been one of the favourite collecting grounds for Cephalpods, Euomphalus, Spirifers, and other Brachipods.

(*b*) Bellman Quarry Hill is of inconsiderable height, but forms a low rounded knoll. It consists largely of crinoidal debris, sometimes quite well bedded, sometimes obscurely bedded. The same plates and stems weather out as on Salt Hill, and cups or heads are quite plentiful. Shells sometimes come out on weathered masses in great perfection. There is the same iron-oxide and weathering of the limestone to a brown clay. Stalagmitic deposits are quite good. There is a remarkable breccia made up of fine-grained pieces of limestone and crinoidal fragments mixed together. This breccia is *interbedded* with the ordinary crinoidal and shell limestone.

(*c*) Worston Hill shows more of the knoll character; it rises somewhat sharply from the plain of Pendleside shales, and has the familiar rounded appearance. There is the same crinoidal debris, with the same rolled shells weathering out perfectly on long exposure. There is the same breccia, this time in greater abundance; at least I have seen more of it, and it is again clearly interbedded with the irregularly stratified crinoidal and shell debris.

(*d*) Worsaw is the highest and by far the most conspicuous of the series. It rises to a height of 725 feet above Ordnance datum, or more than 300 feet above the neighbouring plain. There is again the crinoidal and shell debris, sometimes quite well bedded, sometimes very obscurely bedded. Occasionally the limestone may be described as flaggy. The dips in this and in the knolls of Salt Hill, Bellman, and Worston are fairly consonant. They are almost uniformly towards the plain, and the grit hills of the Pendle escarpment. In the case of Worsaw there are plenty of exposures, and, excepting in one case, the dips are fairly easy to determine and are as uniform in direction as can be expected in a folded country. The slope facing the low plain is a true dip-slope. The slope on the other side is an escarpment slope, and the beds may be seen dipping into the hill in many places. The following diagram shows these most important features. Fig. 2.

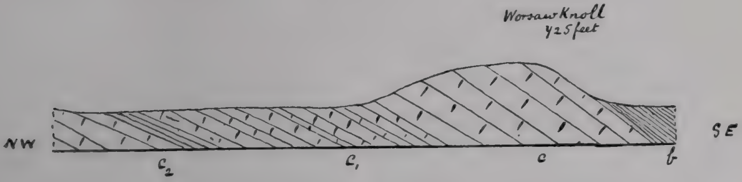


Fig. 2.

SECTION THROUGH WORSAW KNOLL ACROSS THE STRIKE.

b = Pendleside Shales.
c = Upper Limestones, very "massive" as a rule
c_1 = Limestones, more "flaggy" ... ...
c_2 = Limestones with shales ... ...
Carboniferous Limestone Series.

There are swallow-holes on the top of this mass, and stalagmitic deposits may be found in the wide joints, and I have also obtained fluor and pyrites there.

(*e*) The next "knoll" is Gerna, though there are some apparently semi-detached masses or much reduced knolls between Worsaw and Downham village. Gerna appears as an island, and is so mapped. The shales all round it are mapped as the same, but those south of the "island," striking with the beds in front of the knolls previously described, contain the Pendleside fauna—*Pterinopecten papyraceus*, *Posidoniella lævis* and *P. minor*, &c., whilst the shales north of the Gerna mass are lithologically different, and contain a different fauna, the fossils being those of the limestone massif, as found at Thornton and Rain Hall, for instance. If the beds were coloured according to the fauna, the deep blue of Gerna would then be connected directly with the blue of the Chatburn anticlinal.

The structure of Gerna is not so manifest as in the other cases. There is one quarry, and a few rather poor exposures. In the quarry the dips are in accord with those of Worsaw and the other knolls to the west. The knoll is, however, covered with grass for the most part, and the small exposures seem to be mainly in the obscurely bedded limestone, and the dips are not easy to make out. On the survey map they are given as quaquaversal, and this would indicate the probability of some roll in the beds. The limestone at Gerna is exactly like that in the knolls already noticed. The hard unpromising limestone becomes easy to work for fossils when it has weathered and the matrix of calcareous mud is more or less dissolved away. I have got excellent fossils from the weathered and decomposed material. The same tufa and stalagmite are noticeable, and I have got perfect cubic crystals which have a core of pyrites, but are converted into limonite on the outside. Here, as always, there is evidence of the effects of long-continued percolation of water containing oxygen, carbon dioxide, &c. In one joint I found a well-worn quartz pebble, just such as occurs in the grits.

(*f*) Sykes knoll stands up as a long narrow peninsula. It consists in part of crinoidal debris, and in part of fine-grained, apparently almost unfossiliferous, limestone. Exposures are not very numerous, but the dips on the whole seem to agree with the general direction in the other knolls. A fault runs alongside, and it is separated from Twiston knoll by a river valley.

(*g*) Twiston knoll is the last of the series. It contains very fine crinoidal debris, with occasional shells; this is sometimes obscurely bedded, but in places it is most clearly well-bedded.

There is again a fine-textured, apparently unfossiliferous, limestone at the base of the strata forming the knoll. There is another fine-grained deposit higher in the series, and the more obscurely stratified crinoidal and shell deposits seem to be interbedded. The dips are nearly all southwards.

To sum up, the structures and structural relations common to this series of seven knolls are as follows:—(1) The occurrence of crinoidal and shell debris, with occasional corals and polyzoa; (2) the presence of rolled and broken shells; (3) the occurrence of mineral deposits—stalagmite, fluor, pyrites, and iron oxides; (4) the presence of interbedded breccias made of fine-grained material and fragments, principally crinoidal; (5) the variation in the character of the bedding, well-bedded material alternating with more obscurely bedded deposits in every knoll; (6) the general agreement of the dip of the beds, with only such irregularities as are likely to occur in a folded country, and which can be matched in every part of the Craven Lowlands.

It is now necessary to consider the strata on each side of this knoll line. To the south there are the fine black shales, with characteristic thin limestones passing upwards into the shales with grits. These are characterised, as Dr. Hind and Mr. Howe have shown, by a well-defined fauna (see also the Survey memoir on the Burnley Coalfield). On the north side, that is behind the knolls and towards the middle of the Chatburn-Clitheroe anticlinal, there are more flaggy limestones, with mudstones and soft shales. The beds have still the same general dip. They may be well studied in the immediate neighbourhood of Downham and in the brook sections between Worsaw Hill and Chatburn. These beds contain the same general fauna which occurs at Thornton-in-Craven, at Rain Hall, at Newsholme, and other places in the area coloured dark blue on the survey map. (I hope in a future paper to give further particulars and detailed lists of the fauna of Thornton and Downham.) These shales and "mudstones" are not on the same horizon as the shales south of the knolls, the faunas being quite different. The recognition of the Pendlesides, as constituting a distinct stratigraphical series, is, in my opinion, most important. Whether these beds are eventually known as the Pendleside series or as the upper shales with limestones matters less than the insistence on the fact that they are quite distinct lithologically and palæontologically from the various beds of the series below. The greyish limestones, the blue limestones, and the variable shales of the Carboniferous Limestone series contain, on the whole, the same well-defined fauna. This fauna is quite different from that of the Pendleside shales and limestones immediately succeeding them. Grey or "white" limestones occur not only in the knolls at the top of the "massif," but also nearer the base of the series exposed in the Chatburn district. The Carboniferous Limestone is at least 2,500 feet thick unless there is repetition of the beds, and whether there is much repetition can only be determined by careful collecting from every horizon. I hope it will be possible to work out the whole 2,500 feet or so of the limestone massif in zones, as has been so ably done by Dr. A. Vaughan for the Bristol area, and I commend a share in the work to any members of our society who can find time to assist.

The general succession of the beds from the grit escarpment of Pendle through the most conspicuous of the knoll hills, Worsaw, is as follows :—

Millstone Grits.
  Pendleside shales with limestones and grit bands.
  Greyish-white crinoidal limestone.
  More flaggy limestone.
  Flaggy limestones with shale bands.
  Blue and grey massive limestones, with shales.
  Thin bedded dark limestones and shales.

The beds from the base of the Pendleside Shales downwards contain the same general fauna.

The succession would then be as in Fig. 3.

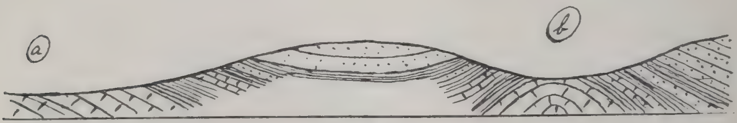


Fig. 3.

DIAGRAMMATIC SECTION THROUGH THE HILLS BETWEEN THE CRAVEN LOWLANDS (A) AND THE LOTHERSDALE ANTICLINAL (B).

Vertical scale exaggerated.

The partial isolation of the Worsaw mass and its consequent knoll-like appearance is partially, if not wholly, accounted for by the trend of the old river valleys. There is a manifest longitudinal river course which has produced the rather wide plain between the Worsaw mass and the Chatburn ridge. The river seems to have run behind the knoll mass, and to have flowed out, between it and the Worston mass, into the valley of Pendleside beds, and the course is marked at the outer end by a tiny stream now. The river has been captured by a transverse stream, and it now flows off across the strike through the lower part of Chatburn village. Worston knoll and the low hills of Bellman and Salt Hill are similarly accounted for.

The more flaggy limestones and the limestones with shales have been more readily worn down than the massive obscurely bedded crinoidal and shell debris higher in the series, and hence these latter beds now stand up as the knolls, the southern faces of these knolls being the well marked dip-slopes. The soft Pendleside shales immediately succeeding these limestone beds with their breccias have been cut down by the longitudinal stream drainages, and have thus intensified the knoll-like appearance.

I do not deny that there may have been lenticular thickenings of these deposits, but it seems to me that Sir A. Geikie's explanation completely expresses the facts as regards deposition. He says, "The original reef-knolls described by Mr. Tiddeman from the Clitheroe district appeared to me to be due to the irregular aggregation of submarine organic debris *in situ*, though I could not detect any true reef structure."*

The present appearances are due then, partly to the nature of the deposits, and partly to the ordinary agents of denudation acting differentially on the beds of varying texture.

It is noteworthy that the organic debris and breccia deposits with their rolled shells and other peculiarities are absent from the Barnoldswick-Thornton area. There the beds which lie immediately below the Pendleside shales and limestones are blue limestones with abundant shale bands. The fauna of these blue limestones and shales is, however, as nearly that of the knoll deposits of Chatburn as could be expected. I hope to show in a subsequent paper that the crinoids, echinoids, corals, and polyzoa are identical in the Thornton and Rain Hall beds of blue limestone and muds and in the limestone knolls. The brachiopods are only different in that muddy water forms predominate in the one, whilst Spiriferid and Rhynchonnelid forms are plentiful in the other. The difference is quantitative and not qualitative.

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* Text Book of Geology, Fourth Edition, vol. ii., p. 1041.

An apparent peculiarity of the knolls to which attention has been very often drawn is their extremely fossiliferous character. This is partly due to secondary causes. It is well to remember that some of the knoll limestones are apparently unfossiliferous until they are examined in thin section or until their fossils are "weathered out." There are some recent exposures in the Twiston knoll which are apparently quite unfossiliferous, whereas all the weathered surfaces and all the old walls on and near that knoll show plenty of fossils.

The shells and crinoids and other remains of organisms are held together by a fine calcareous cement. Long-continued weathering attacks this cementing matter, and reveals the megascopic fossils, and renders them quite easy to extract. Everyone who has worked on the limestones knows how beautifully fossiliferous are the old walls, and how much better their western faces are than their eastern faces. It is the same in the joints of the knoll limestones. Masses which appear quite hopeless on newly fractured surfaces show excellent fossils of various types where the bedding planes have been long exposed or where the joints are accessible.

Now the dip of the knoll limestones is evidently very favourable to the action of percolating water, with its dissolved gases and organic acids. In the more thinly bedded masses the action reveals fossils along the frequent joints and along the parting planes of the bedding, as has been already pointed out. In the more irregularly bedded limestones the meteoric waters have occasionally percolated throughout the whole mass, the cementing material has been partly dissolved away, the iron compounds converted into hydrates, the remainder of the cement converted into a yellow or brown clay, and the shells and other fossils left so that they can be lifted out with the fingers.

The progressive development of this phenomenon may be well seen in many new cuttings, the upper part is fossiliferous, the lower part apparently very much less so. Similar appearances may often be seen in the regularly bedded limestones of the districts where there are no knolls in the restricted sense.

It may be well to recall the evidence for long continued drainage in the interior of these knolls, which are so admirably situated for the manifestation of its full action—frequent stalagmite deposits, the fluor along the joints (this is not common), the pseudomorphs of Limonite ($2\,Fe_2O_33H_2O$) after Pyrites, and the occasional grit pebbles found in the underground channels.

It remains to be said that these observations and conclusions refer to the Downham and Clitheroe knolls in particular, and whilst it is quite likely that other knolls in other areas may allow of a different explanation, yet I think that at least some of these knolls may be thus accounted for.

I wish in conclusion to express my indebtedness to the writings of Prof. Marr and Messrs. Hind and Howe on this subject, and especially would I express my obligation to the work of Mr. Tiddeman. Whilst venturing to differ from some of his conclusions, I am continually feeling in my work in Craven how much I owe to his pioneer work in this part of the country.

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NOTE ON A NEW SECTION IN THE GLACIAL DRIFTS OF HOLDERNESS.

BY T. SHEPPARD, F.G.S., AND
J. W. STATHER, F.G.S.

On account of the important part which the Holderness drifts have played in connection with the theories of the glaciation of the country generally, it is proposed to place on record particulars of what is perhaps the finest artificial section in the English glacial series extant. The section has been made in a rounded hill, which is situated between the well-known Kelsey Hill and Burstwick gravel pits, and lies between the 25 ft. and 50 ft. contour lines. (Fig. 1.)

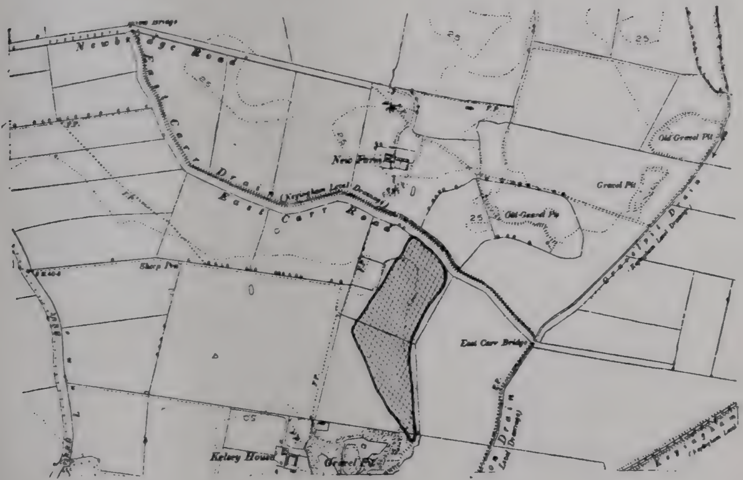


Fig. 1.

MAP OF KELSEY HILL DISTRICT, SHOWING POSITION OF THE NEW PIT.

In 1902 the North Eastern Railway Company commenced excavations by making a cutting across the eastern flank of the hill. Since then this cutting has been extended and deepened, and details of the beds as exposed from time to time have been carefully sketched, and in this way particulars of the structure of the entire hill have been secured.

Fig. 1 illustrates the easternmost section seen, and is entirely in boulder clay. Fig. 2 represents the same face when cut back 50 yards, and shows round tongue-like masses of the shelly gravel appearing at the base of the cutting from beneath the boulder clay. Fig. 3 represents the section parallel to the former, but still further west, and shows the shelly sand and gravel taking the place of the boulder clay almost throughout the section. Four of these sketches are given on Plate XXI., and illustrate parallel sections right across the eastern flank of the hill from north to south, and about 50 yards apart.

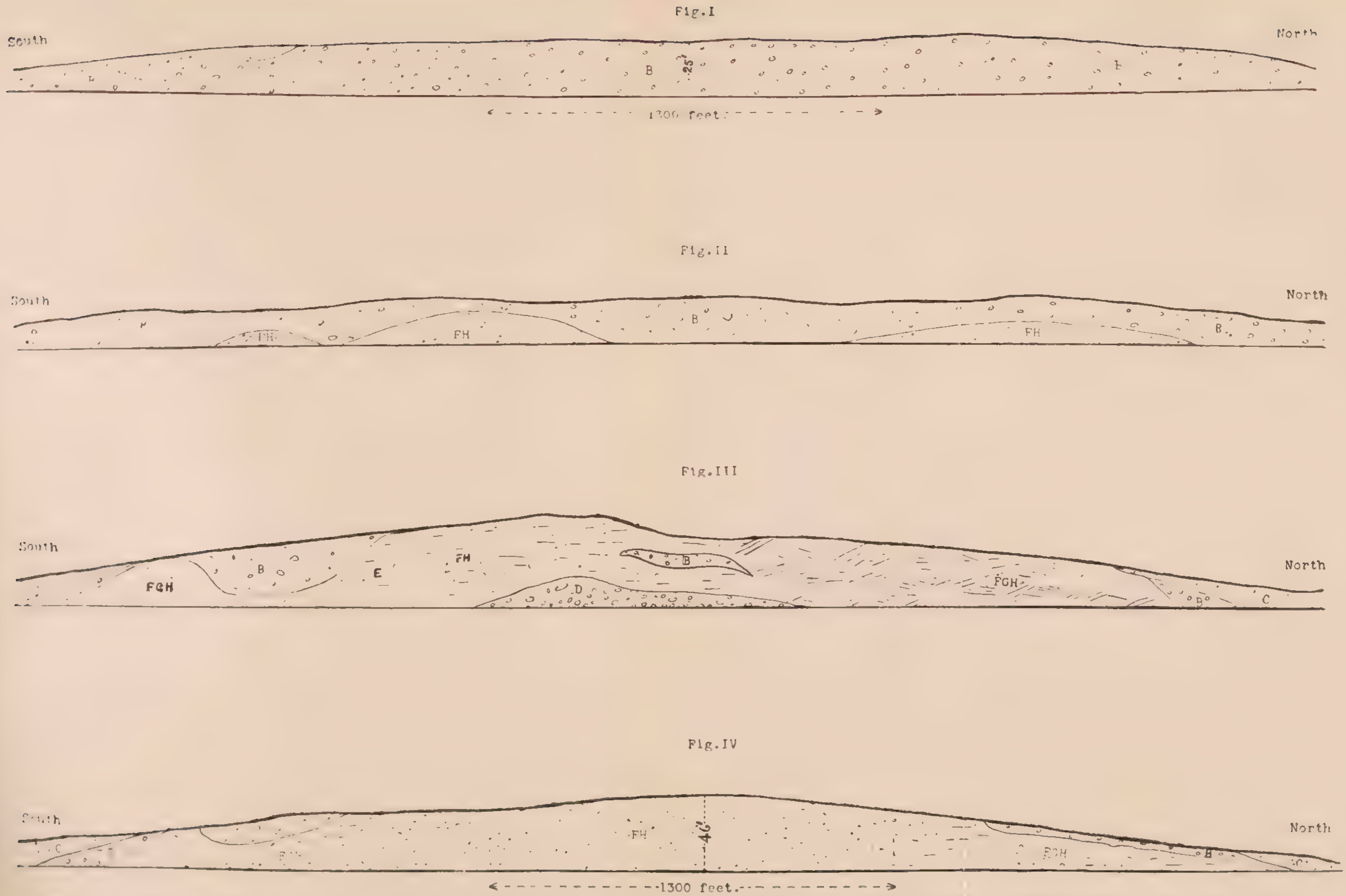
The present section (Fig. 4, Pl. XXI. and Pl. XXII.) exhibits 46 ft. of shelly gravel and fine sand in the centre, with no boulder clay above, though the latter flanks the deposit at both ends. The cutting is here approaching the crown of the hill, from which the boulder clay has been sub-aerially denuded.

At the present time the section is 1,300 ft. long and 46 ft. high in the centre, from which point it gradually slopes to the north and south.

A detailed examination of the sections as they were exposed showed conclusively that the core of the hill consisted of a conical gravel mound, similar to those at Kelk and other places nearer Bridlington, which had been over-ridden, kneaded out, and generally disturbed (Pl. XXIII.) by an advance of the ice, which plastered the sides with boulder clay and filled in any irregularities of the surface with the same material.

The direction of this movement was obviously from the north, from which point also came the water which gave a current-bedded structure to parts of the gravel.

The shelly gravel occurs in a large mass forming the centre of the hill, but parts of this have been torn away, and, as in the case of the boulder clay, have been incorporated with the coarser gravelly material. Thus in more than one place an irregular seam consisting almost entirely of shell-fragments may



Figs. I., II., III. and IV.—Diagrams illustrating the changes in the structure of the hill as the section advanced from the edge towards the centre. The distance between the sections shown in Fig. I. and Fig. IV. is 110 yards; the total length of the section is 1,330 feet, and height in the centre 46 feet.

B—Boulder Clay (Hessle Type).	**F**—Coarse Gravel.
C—Redistributed Boulder Clay.	**G**—Sand.
D -Strong Boulder Clay.	**H**—Shells.
E -Current Bedded Shelly Gravel	

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXI.

be seen to occur amongst coarse ferruginous gravel, which contains hardly any molluscan remains. These transported masses have evidently been moved whilst in a frozen condition, and the faulting and frequent displacing which occur in the sand and gravel in other parts of the section (Pl. XXI., Fig. 3) also point to the same conclusion.

In Mr. Clement Reid's "Geology of Holderness" an excellent list of molluscan remains from the adjacent Kelsey Hill pit is given. This list we are able to extend by the names of a few species, but they do not add much to the evidences of the former climatic conditions. A list of the specimens from the new section is given in the appendix. The shells and shell-fragments which occur in extraordinary numbers in certain parts of the gravel are, with one exception, exclusively marine, and point to greater cold than now obtains in the district. The exception is the well-known *Corbicula fluminalis*, a strong bivalve shell which abounds, and indicates fluviatile conditions. The presence of this shell may probably be accounted for by the fact that the old Humber mouth, as proved by borings, existed under Holderness, in the vicinity of these pits.

Interspersed with the gravel are bones, teeth and horns, of various mammals, some of which bear the teeth marks of hyenas. Unfortunately the steam navvies now in use do not enable the bones to be detected so well as when the earlier pits were excavated by hand. The result of this is that the specimens from the section are not so numerous, and most of them have been picked up from the gravels by local geologists. They include the bones of the mammoth, walrus, bison, horse, red deer, and elk. The mammalian remains are similar in character to those recorded from the buried cliff at Sewerby; some of them have been water-worn and others have not. Their presence in the gravel, where they occur mixed up with pebbles, may be accounted for by the supposition that they were gathered up from the beach of the old Holderness bay by the advancing glacier.

The boulder clay occurring on the flanks of the hill, which in some places is as much as 15 ft. in thickness, is of the foxy-red

Hessle type, and contains few boulders, which are generally of small size, and of which a very large proportion consists of Cheviot rocks. This boulder clay is surmounted by a very loose, earthy material, containing a greater proportion of pebbles, and appearing to be redistributed drift. This in all probability has been washed from the top of the hill, which is now entirely denuded of boulder clay.

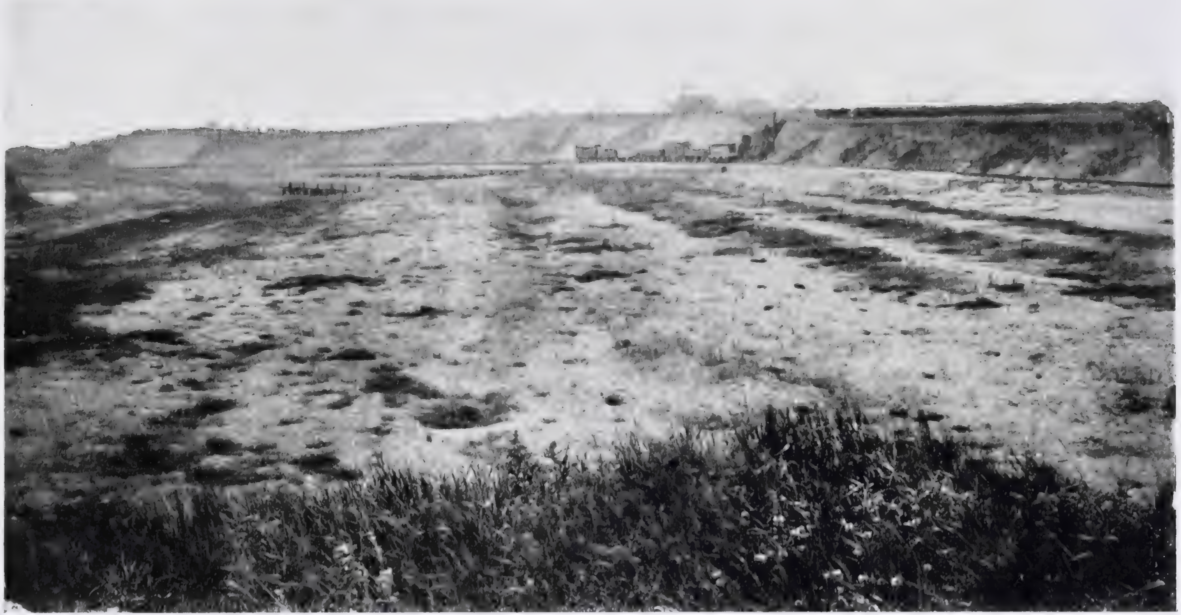
The gravel varies very much in character ; in places it is exceedingly fine, consisting almost entirely of chalk and shell fragments, with a little sand ; in others it is coarse, and partially cemented together either by oxide of iron or by lime. In some parts of the gravel beds of sand occur, which are of a very fine character, and contain a few shell fragments. The mammalian remains are usually found in the coarse gravel.

The pebbles contained in the gravel include a great variety of rocks common to the east coast drifts, including augite-syenite and rhomb-porphyry from Christiania, basalt and Carboniferous Limestone from Teesdale, and Liassic, Oolitic, and chalk pebbles and fossils from the north-east coast of Yorkshire. A few Scottish rocks can also be detected. Many of the chalk pebbles are bored by *Saxicava* and *Pholas*, the shells of which are frequently in position in the crypts.

The whole of the evidence contained in the new section, as read by the present authors, seems to indicate that the gravel is morainic in character, and has been disturbed and altered by an oscillating ice front, which probably on more than one occasion over-rode the moraine. This was after the deposition of the basement boulder clay, which occurs at the base of all the Holderness drifts. Borings at Kelsey Hill prove a boulder clay under the gravel, and whilst this is in all probability the "basement" clay, it is of course difficult to decide by a core from a boring.

We see no evidences of a mild inter-glacial period in this very excellent section.

We beg to thank the Divisional Engineer of the North Eastern Railway Company, Mr. Edward Smith, and his staff,



Photographed by J. T. Dyson, Hull.

GENERAL VIEW OF THE CUTTING, KELSEY HILL.

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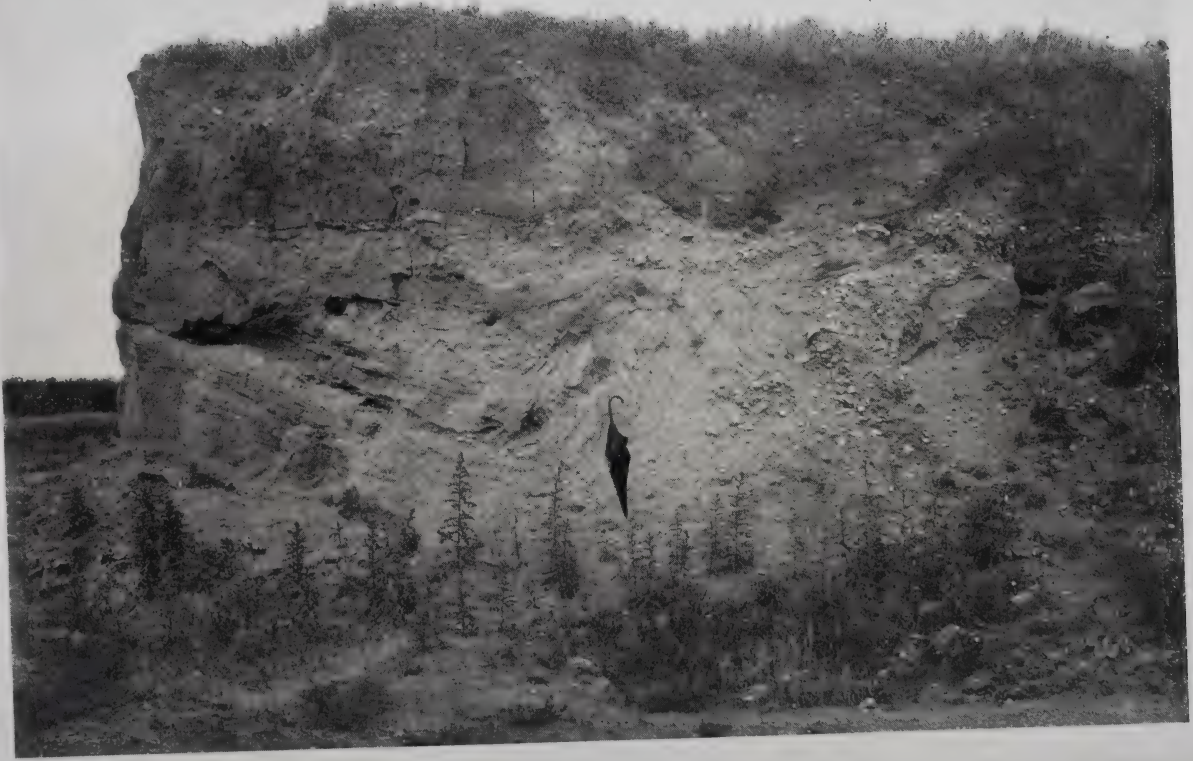


Photographed by J. T. Dyson, Hull.

KELSEY HILL. VIEW AT NORTH END OF SECTION, SHOWING SAND AND CONTORTED BEDS OF GRAVEL SURMOUNTED BY BOULDER CLAY AND REDISTRIBUTED DRIFT.

Vol. XVI. Plate XXIII.

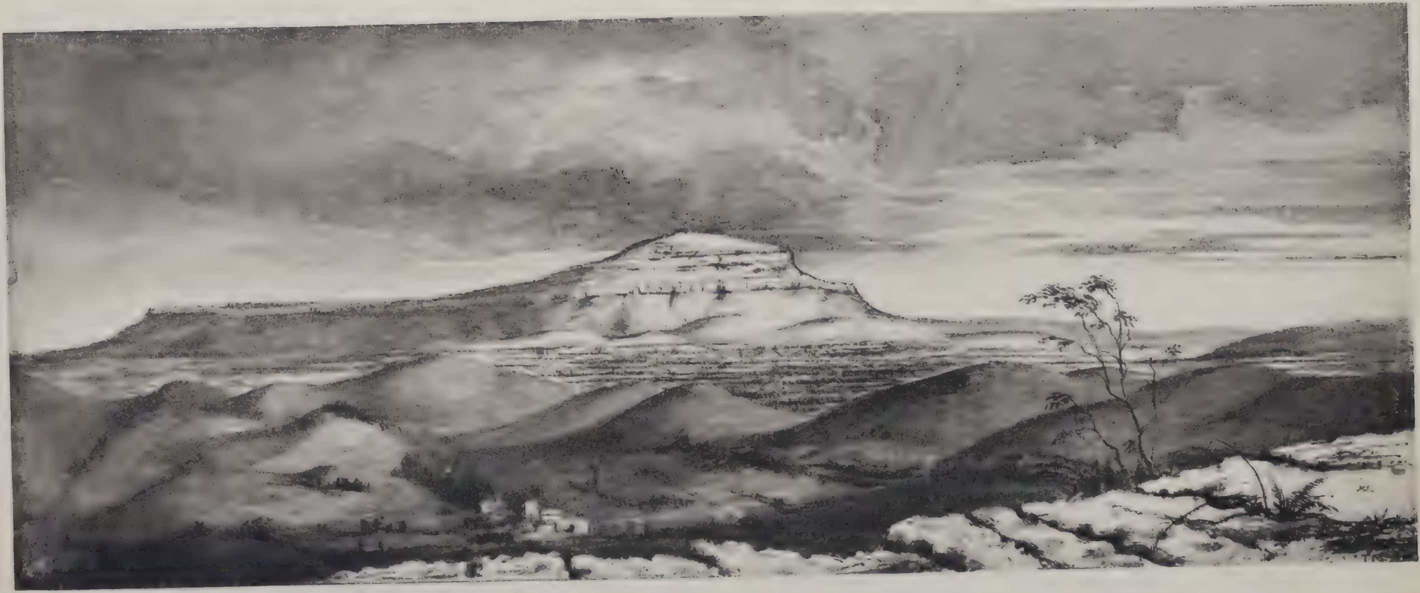
for the facilities they have given us in our work, Mr. G. Sheppard for assistance in collecting, Mr. R. Bullen Newton for identifying some of the shells, and Mr. J. T. Dyson for the photographs.

APPENDIX.

LIST OF SHELLS, ETC., FROM THE NEW SECTION IN THE HOLDERNESS GRAVELS.

Terebratulina caput-serpentis.
Balanus crenatus, Brug.
Anomia ephippium, L.
Astarte borealis, Chemn.
Astarte compressa, Mont.
Cardium edule, L.
Corbicula fluminalis, Müller.
Cyprina Islandica, Lam.
Cytherea chione, L.
Donax vittatus, Da C.
Mactra solida, L.
Mactra subtruncata, Da C.
Mya arenaria, L.
Mya truncata, L.
Mytilus edulis, L.
Nucula nucleus, L.
Ostrea edulis, L.
Pecten Islandicus, Müller.
Pholas crispata, L.
Saxicava arctica, L.
Scrobicularia plana, Da C.
Tellina Balthica, L.
Tellina obliqua, J. Sow.
Venus gallina, L.
Dentalium entalis, L.
Buccinum undatum, L.
Hydrobia ulvæ, Pen.

Lacuna crassior, Mont.
Littorina rudis, Maton.
Littorina littorea, Linn.
Murex erinaceus, L.
Nassa reticulata, L.
Natica clausa, B. & S.
Natica Grœnlandica, Beck.
Natica Islandica, Gmel.
Pleurotoma pyramidalis, Strom.
Pleurotoma turricula, Mont.
Purpura lapillus, L.
Scalaria communis, Lam.
Trochus cinerarius, L.
Trophon antiquus, L.
Trophon gracilis, Da C.
Turritella terebra, L.
Hima incrassata, Müller.
Patella vulgata, Lin.
? Bittium reticulatum.
Polyzoan.
Spines of Echinus.
Crab Claw.



PENYGENT FROM INGLEBOROUGH.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXIV.

INGLEBOROUGH.

PART V. DEVONIAN AND CARBONIFEROUS.

BY T. M^cKENNY HUGHES, M.A., F.R.S., WOODWARDIAN
PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF CAMBRIDGE.

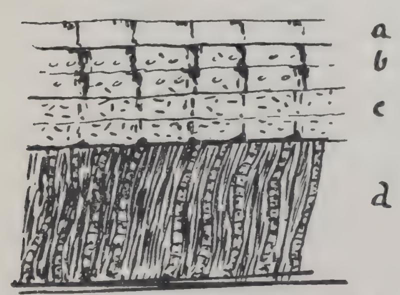
I have given great prominence to the discussion of the character and relations of the Bala and Silurian rocks because of the great interest attached to this easternmost outcrop exposed in the deep valleys which have been carved out on the east and west of Ingleborough, but this is essentially a country of Carboniferous rocks.

As we stand on the great limestone terrace of Ingleborough (see Pl. XXIV.), and look out east across the valley of the Ribble, we see the bold outline of Penyghent, owing its profile to the alternations of sandstone, limestone, and shale which have differently resisted the various denuding agents that have for ages been at work upon it.

The top of it consists of beds higher in the series than any we have on Ingleborough, and the first shoulder from the top corresponds to Ingleborough's cap of Millstone Grit. The next shoulder is due to the massive sandstones which make up the upper part of the Yoredale rocks (the Hawes Flagstone Series), while the top of the Mountain Limestone on which we stand is seen at the foot of the steeper slopes opposite, and its scars are visible here and there projecting out towards Ribblesdale. Though we know that Bala and Silurian occur all along the bottom of the valley from Horton below us, and as far south as Stainforth, we see no features due to them. The conspicuous rounded hills are the moraine mounds of the receding glacier-ice which seems to have been long arrested here. Lower down we find the Bala and Silurian almost continuously beneath the great unconformity, and here and there in *roches moutonnées* in the valleys below, but, except in Crummack-dale, we rarely see features obviously due to them. But we have here great opportunities for studying one phase, at any rate, in the incoming of the conditions under which the Carboniferous rocks were laid down.

Playfair, in his "Illustrations of the Huttonian Theory," 1802, pp. 217–219, says, "I shall mention only one other [instance where the secondary strata are seen lying horizontally on the primary] which was discovered by Lord Webb Seymour and myself at the foot of the high mountain of Ingleborough, in Yorkshire. As we went along the Askrigg road from Ingleton, about a mile and a half from the latter, an opening appeared in the side of the hill, on the right about 100 yards from the road, formed by a large stone, which lay horizontally and was supported by two others standing upright. On going up to the spot we found it was the mouth of a small cave, the stone lying horizontally being part of a limestone bed, and the two upright stones vertical plates of a primary argillaceous schistus. The limestone bed which formed the roof of the cave was nearly horizontal, declining to the south-east; the schistus nearly vertical, stretching from north-west by west to south-east by east. The schistus, though close in contact with the limestone, seemed to contain nothing calcareous and did not effervesce with acids in the slightest degree."

This description, written more than 100 years ago, evidently refers to a small cave near Dale Barn, on the south-east side of Chapel-le-dale, north of which the following section is seen (Fig. 1), which explains how it happens that the stream running



a. Grey Limestone.

b. Grey Limestone with quartz pebbles and a few chips from the Green Slate Series.

c. Limestone full of fragments of the immediately underlying rock, i.e., Green Slate Series.

d. Alternations of slate and thin sandstones to 2 inches each in thickness.

Fig. 1.

SECTION SEEN NORTH OF DALE BARN, CHAPEL-LE-DALE.

Scale, about 8 feet to 1 inch.

through the cave has eaten its way down through softer schist and left the hard beds of sandstone vertical on either side, as described by Playfair.

There are many examples along this part of the valley of caves formed in this way, namely by the water, which has found its way down along joints to the very base of the Mountain Limestone, eating out channels in the underlying schists, and forming caves in the schist as well as in the limestone (see Fig. 2).

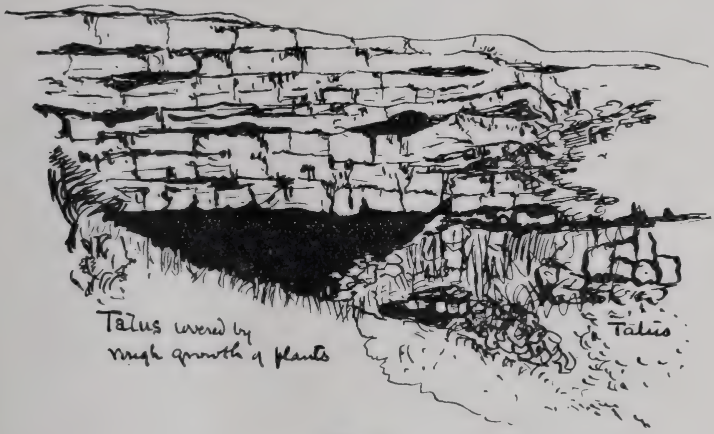


Fig. 2.

CAVE IN SCHISTS UNDER MOUNTAIN LIMESTONE, BELOW RAVENSCAR, EAST SIDE OF CHAPEL-LE-DALE.

Playfair goes on to say, "At the spot just described no breccia appeared to be interposed between the primitive and secondary rock; but we found a breccia at another point of the same junction not far distant. This was at a cascade in the River Greata, called Thornton Force, about two miles and a half from the place just mentioned. The Greata here precipitates itself from a horizontal rock of limestone, and, after a fall of about 18 or 20 feet, is received into a basin which it has worked out in the primary schistus. This schistus is in beds almost perpendicular; it exactly resembles that which has just been described, and stretches nearly in the same direction. On the south side of the river a breccia was seen lying upon the schistus, or rather, it might be said, that the lowest beds of limestone contained in them many rounded fragments of stone, which, on comparison, exactly resembled the schistus underneath."

The old fashioned terminology does not lessen our appreciation of the accuracy of Playfair's early observations. The schistus is spoken of as primary or primitive, while secondary includes the Carboniferous, and is not the same as Secondary, with a capital S, of later times. It is interesting to read the first impressions of this accomplished observer as he approached the section, and his description of the appearance of the mouth of the cave where the great masses of horizontal limestone looked at a distance like lintels artificially supported by upright jambs on either side of the entrance.

We can fully agree with him that "the circumstances are such as we cannot expect to see very often exemplified."

Professor Phillips,* who did so much for the geology of Yorkshire, and to whose work we shall have so frequently to refer in describing the Carboniferous rocks of Ingleborough, did not, in his earlier descriptions of this district, say much about the Basement Bed. One cannot but realise, even from the short descriptions which I quote, what a wonderfully good observer Phillips was.

He says in one of his earliest papers,* "The lower beds of the northern range of limestone resting on slate are commonly filled with pebbles of slate and quartz. Generally very large boulders of slate lie at the bottom, and the higher beds contain less and fewer pebbles till the character of conglomerate finally vanishes in common limestone. The pebbly beds may be known at a distance by their horizontal laminæ and weather-slits, which contrast decidedly with the vertical fissures of the equal-grained rocks above."

He points out that this Basement Bed, in its relation to the Mountain Limestone, and its character and composition, closely resembles the beds found in the corresponding position in Wales and the South-west of England. After describing the pebbles found in the red conglomerate in the Lune valley—the limestones which he mentions, I may explain in passing, are fragments of Bala Limestone—he adds (p. 14), " By this list will appear the limited extent of the current which brought together these pebbles—no trace of granite, syenite, porphyry, greenstone, amygdaloidal slate, or any of the Cumbrian rocks which are remote from the valley."

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* On a group of Slate Rocks ranging E.S.E. between the rivers Lune and Wharfe, from near Kirby Lonsdale to near Malham; and on the attendant Phænomena. By John Phillips, F.G.S., Hon. Memb. of the Yorkshire, Leeds, and Hull Philosophical Societies. Read Dec. 21st, 1827, and Jan. 4th, 1828, Trans. Geol. Soc., vol. iii., 2nd Series.

" The pebbles vary in size, number, and degree of cohesion to the matrix in different beds. . . . They are but feebly cemented in the clay and sand, and may be detached by a blow of the hammer, leaving a concave smooth impression. In some cases I have imagined that one pebble indented another."

He adds (p. 15), " This intermediate or transition group, until lately little noticed by geologists, is of great importance in all questions concerning the comparative age of unconnected deposits of the older Mountain Limestone Series."

Professor Sedgwick in his paper on the Lower Palæozoic Rocks at the Base of the Carboniferous Chain between Ravenstonedale and Ribblesdale,* says that " At Thornton Force there are some traces of calcareous conglomerates immediately under, and partly penetrating, the bottom beds of limestone. They seem to represent the Old Red Sandstone in a very degenerate form, and they disappear in some of the neighbouring sections. Indeed, throughout the North of England the Old Red Sandstone, even when developed on a far greater scale, is generally seen in discontinuous masses."

In 1886 I led an excursion of Cambridge students to Ingleborough, where we were joined by Professor Lohest, who, on his return to Belgium, wrote, in conjunction with his friend and master, Professor de Koninck, a short paper on the results of his observations.†

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* Quart. Journ. Geol. Soc., vol. viii., 1851, p. 45.

† Notice sur le parallelisme entre le Calcaire Carbonifère du Nord-ouest de l'Angleterre et celue de la Belgique par L. G. de Koninck et Maximin Lohest. Bulletins de l'Académie Royale de Belgique, 3^me^ Serie, tome xi., No. 6, 1886.

He accepts the correlation of M. de Lapparent that the Calcaire de Tournai is earlier than the Mountain Limestone, and the Calcaire de Visé is of the same age as the Yoredale rocks. After pointing out that the zone of *Chonetes papilionacea* was near the base and was succeeded in ascending order by the zone of *Producta gigantea* and *P. cora*, he goes on to describe our Basement Bed.

" Ordinairement la base du système carbonifère repose aux environs d'Ingleborough sur le Silurien et est constituée par un conglomérat à cailloux de quartz blanc, de quartzites, et de differentes roches Siluriennes. Les cailloux sont cimentés par du calcaire. Cependant en quelques points ou trouve inférieurement au conglomérat calcareux des psammites gris micacés, des schistes verdâtres et un conglomérat à ciment siliceux et argileux. L'ensemble de ces dernières couches comprises entre le Silurien et le conglomérat calcareux n'a souvent que quelques mètres d'épaisseur. L'âge de ce dépôt ou les fossiles font ordinairement défaut peut être discuté. Dans le conglomérat à ciment calcareux les fossiles sont assez nombreux, mais souvent en mauvais état. Nous y avons trouvé le *Lithostrotion basaltiforme*, Conybeare et Phillips, de nombreux *Amplexus* et *Zaphrentis*. Nous avous eu également l'occasion d'y recueillir quelques dents de Placoides, parmi les quelles nous avous cru reconnaitre celles de *Lophodus lœvissimus* L. Agassiz et *Copodus cornutus* L. Agassiz.

L'une d'elles a été trouvée à un mètre environ au-dessus du Silurien. . . .

Nous croyons bien que certaines dents de Placoides recueillées au sud d'Ingleborough sont analogues a celles que l'on rencontre en abondance vers la partie inférieure de notre calcaire carbonifère. Dans le sud ouest d'l'Angleterre, la base du calcaire carbonifère est également caratérisée par l'abondance de ces dents palatales."

" Nous ajouterons que la partie inférieure de notre calcaire carbonifère est caractérisée de même qu'aux environs d'Ingleborough, par la présence de nombreux polypiers se rapportant spécialement aux genres *Amplexus* et *Zaphrentis*."

In the first part of this monograph (vol. xiv., pp. 127–134), after describing the two great sea plains of the North of England, with which all study of the physical geography of our district must begin, and comparing the 3,000-foot plain just touched by the tops of the Lake Mountains and the 2,000-foot plain of the Yorkshire Moorlands with the sea plain on which the Carboniferous rocks of this district were laid down, I pointed out that such inquiries are essential for the right understanding of some of the problems suggested by an examination of the flanks of Ingleborough.

Now we have come to the part of our subject where it is necessary to consider in detail the evidence upon which we rely for our generalisations. We may not be able to find all the data we want to prove each point, but we must take care that there is, at any rate, nothing contradictory to our working hypotheses.

Let us then inquire what is the character of the surface upon which the Basement Beds of the Carboniferous system were laid down.

In the first place we see that the top of the Silurian and Bala Beds, as each comes to the surface by the squeezing, folding, faulting, and denudation to which they have been subjected, do not generally present that broken rubbly appearance that those same rocks have where we know that they have been long subjected to the action of rain and frost, and to the changes of temperature and amount of moisture which we see breaking up the surface of the same or similar rocks to-day.

The newly-exposed face of a glaciated rock is hard and solid, because the sand-charged base of the ice has removed all the soft and weathered part and has cut down into the heart of the rock and then sealed it up and protected it by a covering of impervious clay.

The sea or river also, with its rolling mass of gravel and sand, wipes off all the bruised and rotten rock, and leaves the surface sound and hard, though sometimes jagged.

If we follow the unconformable base of the Carboniferous rocks round Ingleborough we shall find that the underlying rock is, as a rule, sound and solid. Where there appears to be an exception we very often see good reason for believing that this is due to water which has found its way down through the jointed limestone to the impervious base, or that the breaking up of the underlying Silurian or Bala is primarily due to earth movements, of which we can obtain independent evidence (see p. 179, and Fig. 2, near Dale Barn; 188, and Fig. 5).

The surface upon which the Carboniferous system rests at Ingleborough is therefore either a glaciated surface or a sea plain, but not an old land surface unswept by denudation before it was submerged. I have also already pointed out what happens in the adjoining area if we follow this Basement Bed beyond the Ingleborough district. It is thickened out into great but very roughly stratified masses of gravel, sand, and mud, running as far as can be made out in long valleys. This material is made up of the débris of the rocks of the district, and there are no far transported blocks or any evidence of glacial action. This can be studied in the valley of the Rawthey, near Sedbergh, and in that of the Lune, near Kirby Lonsdale, and, further afield still, in the great masses of red conglomerate at the foot of Ullswater.

Referring to these, Mr. R. D. Oldham, of the Geological Survey of India, in a paper read at the meeting of the British Association at Bradford (1900, p. 765), expressed the opinion that they were torrential deposits, analogous to those which he had seen formed at the foot of the hills in Western and Central Asia. He observed also that red soils were much more common in tropical than in temperate regions. He does not discuss the possibility of the material being swept off the adjoining hills into the depths of a gradually submerged fiord, but considers that it was all carried by torrents over areas which were usually dry, with seasonal or periodical bursts of rain. If so, they must rather resemble the cones of dejection at the foot of steeper valleys or the delta-like deposit spread during flood further over the plain beyond.

The interesting speculation suggested by the striated fragments from these beds seen near Helm Knot, in Dent, I have already discussed in the pages of our Proceedings,* arriving at the conclusion that they were all produced by movements in the mass subsequent to its consolidation, a view rendered certain by the fact that they were found along great lines of displacement and there only.

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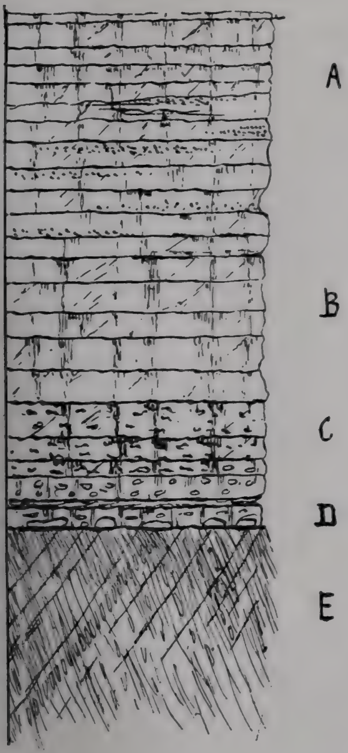
* Notes on the Geology of parts of Yorkshire and Westmorland, Geol. Polyt. Soc., West Riding Yorks., 17th July, 1867.

The large boulders resting on the older rocks at the base of the Carboniferous, such as those under Norber Brow for instance (Fig. 3), are in many respects suggestive of glacial action, but they are not far transported nor striated but just such as lie sporadically on a shore at the present day, where only exceptional storms can shift them at all, while the smaller material is swept from around them.



A. Grey Limestone, with beds and lines of small fragments from the Cambrian (Sedg.) and Silurian rocks and of vein quartz, generally round and about the size of a sweet pea. 20 feet.

B. Grey Limestone, in which fragments and pebbles, as described above, are uniformly and thickly distributed all through. 20 feet.

C. Grey Limestone, with large fragments up to the size of beans. 12 feet.

D. Grey Limestone, with rolled and subangular pieces of Silurian Grit and Mudstone up to 4 feet in diameter, and close by a block 13 feet long occurring at the very base. 2 feet.

E. Bala Shale, with calcareous concretions sometimes forced into coincidence with the cleavage planes.

Fig. 3.

SECTION UNDER NORBER BROW NORTH OF AUSTWICK.

On the whole, therefore, the general consideration of the place of this plain, and the close examination of each section in it, supports the view that, as it stands, it is a sea plain, and that the fragments on it are water-worn and water-borne, though this is not inconsistent with the supposition that there may have been glaciers on the adjoining mountains if there were any high enough to give rise to them.

In the diagram (Fig. 4) I have indicated, by the line A B C D, what I conceive to have been the character of the surface at one stage of the pre-Carboniferous denudations.

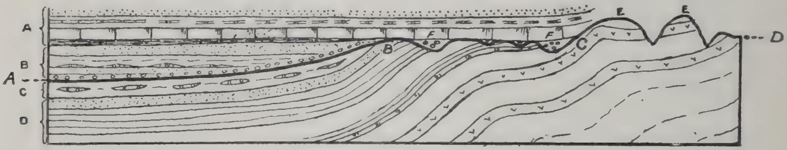


DIAGRAM ILLUSTRATING RELATION OF BASEMENT BED OF CARBONIFEROUS TO THE DEVONIAN.

Fig. 4.

A B C D. The thick line represents the pre-Carboniferous surface.

E E. Sinking mountain land on margin of Carboniferous sea.

F F. Bottoms of valleys in the part of that sinking mountain land, which, before being planed off, had been submerged below sea level and thus protected from further waste.

a. Carboniferous. (Passage.)

b. Devonian, or Upper Old Red, or Basement Bed of Carboniferous. (Great unconformity.)

c. Merthynian, or Lower Old Red, of Carmarthenshire and Herefordshire. (Passage.)

d. Silurian and Bala.

At the right-hand end of the section were mountains, E E, which fed the valleys F F, such as that which we see now full of red conglomerate at the foot of Ullswater, or that which runs by Sedbergh, Barbon, and Kirby Lonsdale.*

The sea arrested sub-aerial denudation and planed off what remained of the land from B to C, that is over the area on which Ingleborough now stands. It may have removed the mountains E E also, as it removed the similar mountains which once existed on either side of F and F. But at the left-hand end of the diagram the land was being depressed earlier and more rapidly, and deposits accumulated over the submerged area, varying according to the distance from shore, the supply of material, and other local circumstances. Here the Lower Old Red or Merthynian, which is stratigraphically the conformable upward continuation of the Silurian, was by subsidence below sea level placed out of reach of denudation, whereas in the northern area it was all swept away. The left-hand side of the diagram represents the conditions prevailing in Devonshire and South Wales, and the right-hand side those of North Wales and the North of England.

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* Mem. Geol. Survey, 98, S.E., p. 15; 98, N.E., p. 14.

Having referred to the observations of earlier writers and to some general questions as to the place of the Basement Beds of the Carboniferous of Ingleborough in geological history; and having discussed the probable conditions under which they were laid down and the associated geographical features produced; it may be useful now to follow them in detail along their winding outcrop, pointing out each more important exposure and calling attention to such variations in character or mode of occurrence as may seem to throw light on the general questions of their age and origin, or to suggest a promising line for further research.

To begin, then, in Kingsdale, we find the Basement Bed well seen west of the old slate quarry north of the great fault. Here there is a thin-bedded grey limestone passing down into a similar series of beds full of white quartz pebbles, and this in turn passing down into a conglomerate, which, where exposed, is somewhat loose and unconsolidated, and composed of quartz pebbles and bits of the underlying slates, with lenticular concretionary nodules of limestone with or without pebbles. This rests on the edges of the slate, here much decomposed, which may perhaps be due to the same cause as that which affected the conglomerate above. About 70 yards further north the grey limestone with pebbles is false bedded and the pebbles sometimes occur in horizontal lines and sometimes sporadically throughout the mass.

The irregular distribution of the pebbles can be seen all along the cliffs on our left as we proceed north towards Thornton Force.

We then come to Thornton Force, which, from its beauty and geological interest, has been as often sketched, photographed, measured, and written about as any place in Yorkshire, and is one of the features impressed most vividly upon the memory of all who have visited these varied and fascinating bits of mountain river scenery. I have quoted above (pp. 178–181) what Playfair, Phillips, and Sedgwick said about it. The basement conglomerate is rather thicker here. Perhaps, indeed, the hollow in which this débris was accumulated determined the position of the joints and bedding planes in the limestone which caused the subterranean waters to be concentrated here. However that may be, we see most of the stream, in fair weather, when the water is low, finding its way through the deep-jointed rock, but in flood pouring over the rim of horizontal limestone. This limestone, with small pebbles occurring sporadically throughout, rests with a sharp line of demarcation on about five feet of grey conglomerate made up almost entirely of angular and subangular fragments of the underlying schists. For the lowest two feet it is very coarse, often containing blocks up to two feet in length.

Following the base of the Mountain Limestone down the east side of the gorge to nearly due west of Twisleton Hall, we find a spring, from the water of which a large quantity of travertine has been thrown down and is being still precipitated, proving that the subterranean waste of the limestone is going on apace and showing how the caves are rapidly formed wherever the water can find an outfall near the base. A spring marks the base south of Twisleton Hall, and again S.W. of Dale Barn, in Chapel-le-dale, but the outcrop is obscured by drift until we get to a point W.S.W. of Dale Barn, where there is an exposure of dark grey limestone with quartz pebbles, while due north of the barn there is a junction section, in which there is an irregularly horizontal bed of breccia about four feet thick, made up of the schists and resting on the crushed edges of the green slates, and a little further on, in an old quarry N.W. of the sheepfold, the Mountain Limestone is seen with a breccia at its base resting on the green slates.

Near Twisleton Dale House some thick, folded beds of a hard coarse quartzose grit in the Green Slate Series resisted denudation more than the softer slates, and gave rise to a pre-Carboniferous hill over which the Mountain Limestone rises in an anticlinal dome, partly due to original deposition along an elevated rounded ridge, and partly to the obstruction offered by the protruding mass during subsequent settling down and compression of the overlying rocks under the pressure of superincumbent strata. This, of course, affects the basement boundary line, which, therefore, bulges out to the N.W. Coincident with this change of conditions on the sea bottom, we find here a large number of fossils at the base of the limestone, and even among the stones of the basement conglomeratic breccia. We first notice that the fragments of the Green Slate Series in the Basement Bed are larger than the average. This is well seen under the cliff W.N.W. of Twisleton Dale House. A little further east, and more nearly due north of the house, there are alternations of beds of conglomerate 8 to 18 inches, with dark grey limestones 12 to 24 inches in thickness. These beds dip about 10° N.E. in consequence of the dome-like structure above described. In them there are found abundantly fine, well-preserved specimens of coral and other fossils. A little further on, N.W. of the sheepfold, which is N. of the stepping stones, we find near some springs several feet of irregular conglomerate and clayey débris at the base of the Mountain Limestone, and a little more than 200 yards further to the N.E. there is a black, fossiliferous limestone associated with the basement conglomerate.

The outcrop of the Basement Bed is now entirely obscured by drift and alluvium, but it must curve round and cross the valley south of the natural feature known as God's Bridge, where the river runs under horizontal beds of limestone. About 200 yards S.W. of this the black limestone is exposed in the river bed, and a crushed black limestone with fossils is seen again near Light Water Spring, and near by a calcareous conglomerate is seen resting on slate. It appears, therefore, that a black, fossiliferous limestone occurs at intervals on both sides of the valley from near Dale House to God's Bridge, and this has never, as far as I know, been thoroughly worked for fossils. Full lists should be made from this well-marked and easily recognised zone in the very base of the Mountain Limestone of our district.

The boundary is not quite clear along High Howeth until we come to the numerous springs and kelds seen for a mile or so from High Howeth to Cold Cotes, among which occur that described by Playfair (*vide sup.*, p. 178, and the sections Figs. 1 and 2). In one we have 18 inches of the conglomerate, made up of fragments of schist, resting on an irregular surface of the Green Slate Series. In the next, which is in the corresponding position on the S.W. side of the valley to the Twisleton Dale House dome described above, there is a fine keld in which one foot of the conglomerate made up of schist is seen, with fossils fairly abundant, and, about 300 yards further S.W., a spring at which about 10 feet of limestone is seen, with coarse breccia on four feet of flaggy, shaly limestone, with plenty of fossils, and resting on the Green Slate Series. About a quarter of a mile further S.W. is another keld, in which the limestone is seen resting upon an irregularly-denuded surface of the Green Slates. Near the 19th milestone from Lancaster we find grey limestone with quartz pebbles and fossils, and near Skirwith there are beds at the base of the Mountain Limestone full of pebbles of Silurian Grit and quartz.

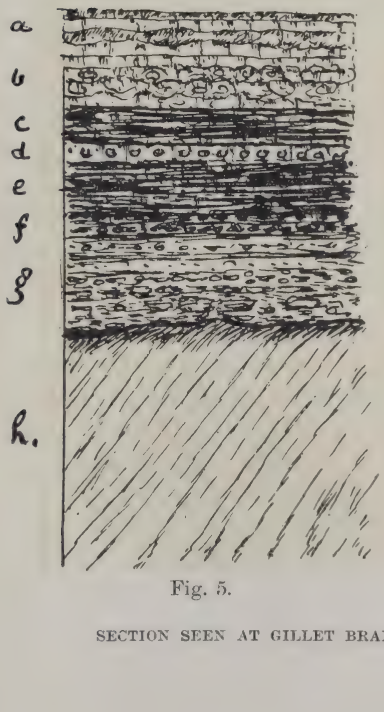
It is important, when following up the local variations in such a deposit as this Basement Bed, not to miss any section which may help to suggest any direction or manner in which the changes are taking place, with a view to suggesting explanations. We now find that our boundary must be carried along a faulted and drift-covered country, but fortunately there are two small exposures near the source of Jenkin Beck which show us that we have got off the Green Slate Series, and that the Basement Bed now rests on the Bala calcareous shales and limestone. A dark grey limestone with quartz pebbles, with a small N.N.E. dip, is seen by the spring north of the great bend in Jenkin Beck, while the base of the Mountain Limestone, with a dip of 10° S.E. is exposed near the source of the stream, resting on Coniston Limestone and Shale, which dips 70°, S. 30° W.

Although here in a crushed corner close to the great Craven Faults the dips are conflicting, the normal succession of the pre-Carboniferous rocks is seen to hold, and about three miles to the S.W. we find the same Bala Limestone and Shale exposed on the north side of the fault in the bed of the streams immediately north of Clapham Tarn, while the Mountain Limestone comes on above it and rises in scars on every side. Now, in order to find the Basement Bed, we must travel about a mile and a quarter due east till we come to the interesting sections under Norber Brow, two-thirds of a mile north of Austwick (Fig. 3). The Basement Bed here also rests on the Bala Limestone and Shale, but, as we follow it along the west side of Crummack Dale, instead of finding the Green Slate Series coming on as we did in Kingsdale and Chapel-le-dale, the order of succession is reversed, and we find the base of the Mountain Limestone resting on a synclinal of Silurian until we get to Austwick Beck Head, where the Bala Beds turn up again.

We begin now to see the red deposits, which by-and-by we shall find in pockets all along the old pre-Carboniferous surface, but generally speaking the material of the basement conglomerate is still *mutatis mutandis* the same in character and mode of occurrence. Instead of the tough green schists we have now more fragments of the hard greywacke and sandy mudstones of the Silurian, but still there is enough to tell us that the Green Slate Series is not far off. About three miles to the north, where the Silurian sandstones begin to make a feature and deflect our boundary line, there are very large blocks of Silurian Grit and Sandstone in the base of the Mountain Limestone, I have already described the Basement Bed at Austwick Beck Head in connection with the Silurian Basement Bed, which is also seen there (vol. xiv., p. 338, Fig. 14 and Pl. L.).

We now can trace the base of the Mountain Limestone almost continuously, with springs thrown out here and there, and small changes in the character of the rock, down the east side of Crummack Dale. It was in one of the small exposures of the basement conglomerate seen here that I found the teeth of placoid fish, which M. Lohest determined for me as *Lophodus lævissimus* and *Copodus cornutus*. Thence we turn east and pass along under the fine precipice which forms the southern front of Moughton and up the west side of Ribblesdale. In the great quarries south of Arco Wood the sharp line of demarcation between the Carboniferous and Silurian can be well studied. I reproduce an admirable photograph of one of these by my friend Mr. W. H. Banks, of Ridgebourne, Kington (Plate XXV). In it we observe also the unweathered character of the top of the flags and the soundness of the base of the limestone, which often stands unbroken, though undercut by the quarrying away of the flags for long distances.

About a mile further north we come to Gillet Beck, and if we trace this up to where it issues from the base of the Mountain Limestone at Gillet Brae, we shall find as usual that a small pre-Carboniferous trough has determined the collection of the subterranean water and its point of discharge on the outcrop. This section is particularly interesting from the alternations of limestone and conglomerate seen in it, and the opportunity it affords of collecting fossils very low down in the base of the Carboniferous. It is as follows:—



a. Thin bedded limestone, mottled with alternations of a darker or lighter grey; passing down into

b. Nodular earthy limestone. 3 to 4 feet.

c. Light grey calcareous shale. 2 feet.

d. Calcareous conglomerate and breccia. 1 ft.

e. Grey shale. 3 feet.

f. Conglomerate and breccia. 1 foot.

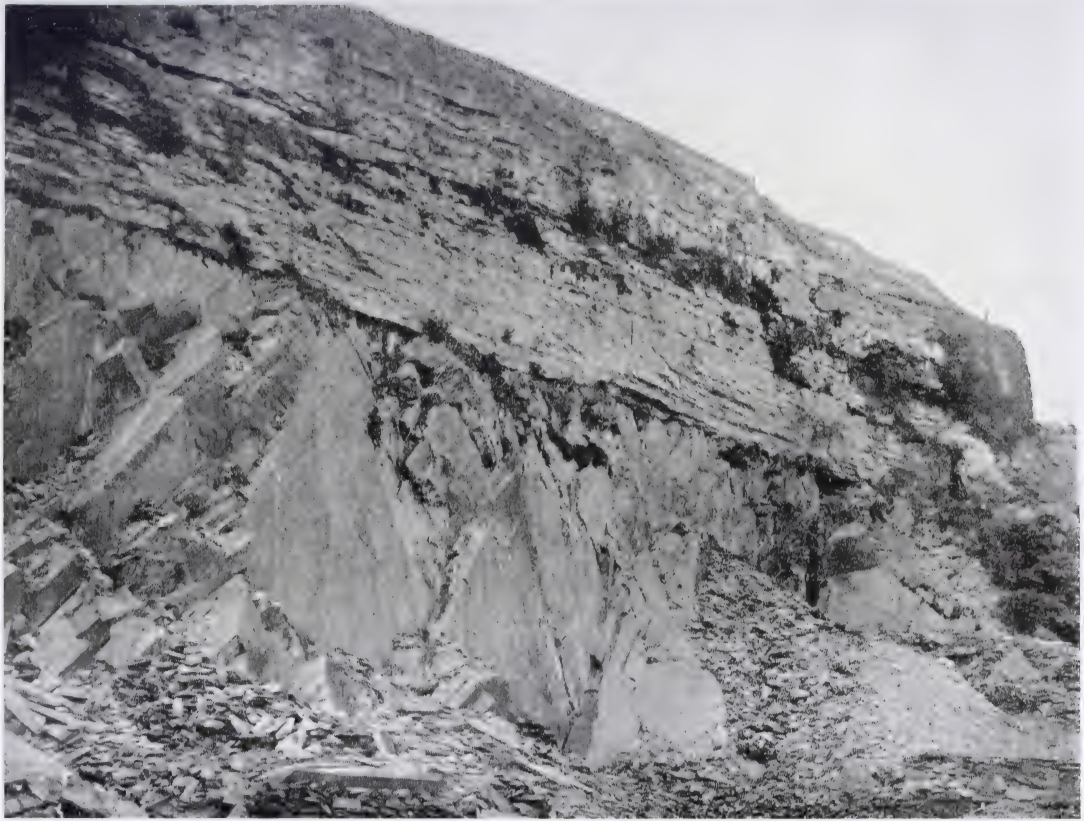
Pebbles and subangular fragments of quartz are common, especially in the limestone, and generally increase in number and size towards the base, where there are some as large as a hen's egg. Pieces of Silurian flags and sandstones also occur in bands. These beds pass down by alternations into

g. A red conglomerate, chiefly composed of partly worn fragments of the underlying sandy slate. At the base the fragments do not appear to be rolled or worn at all, but to have been broken off the weathered edges of the beds on which they rest.

h. Sandy slate or flag, soft and rotten, deeply stained purple, with the top crushed over and broken up so that it is not always easy to tell where the rock crushed *in situ* ends and the overlying conglomerate begins. This supports the view that normally the top of the rock under the Carboniferous Basement Bed is sound and solid, and only where acted upon by the waters at the base, collected in the troughs and channels in the base of the Mountain Limestone, is it decomposed.

Fig. 5.

SECTION SEEN AT GILLET BRAE, NEAR HORTON-IN-RIBBLESDALE.



Photographed by Mr. W. H. Banks, of Ridgebourne, Kington.

UNCONFORMITY, ARCO WOOD QUARRY.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXV.

Less than 300 yards to the north we come to Beecroft Hall Plantation, where there is a somewhat similar section in a similar beck, originating in a similar way in a depression in the base of the Mountain Limestone. Here eight feet of limestone and calcareous shale with quartz pebbles is seen passing down into a red conglomerate 11 feet in thickness, which rests on the sandy flagstone.

Our boundary now crosses the valley, but is entirely obscured by drift and alluvium. It probably runs up-stream for about a mile above Horton-in-Ribblesdale. Returning south on the other side we find, in Dow Gill, crushed rock belonging to the Bala Series with the Mountain Limestone above, and in the stream running out of Bold Bar Plantation, we find 10 feet of thin-bedded limestone with shaly partings, passing down into five feet of calcareous conglomerate, and that into red conglomerate, seen to a depth of 15 feet.

I commend this half a square mile east of Horton-in-Ribblesdale to anyone who wants a nice compact and very varied bit of work in the field. It is the last peep we get of the Bala Beds as they pass under the Yorkshire Moorlands. It has never been thoroughly worked out. The older rocks are in places highly fossiliferous, but the fossils have not been systematically collected or placed on record, or even carefully determined. They show lines of disturbance which have not been laid down, and along the crush-belts yield copper, lead, iron, and other minerals. We here see also the last of the Basement Bed of the Carboniferous in this direction, and can study the gravelly moraine mounds of the later glaciers on the one hand, and the wide spread mountain drift on the other.

We have now to carry a hypothetical boundary for about two miles south over drift-covered slopes of swampy moorland, with nothing to guide us save a spring here and the shape of the ground there, under Hayber Hill, over Studfold High, across Great Moor Head, and round to Calf Close, where we find the Mountain Limestone resting upon six feet of conglomerate. Round the high moorlands of Stainforth and Catrigg the indications are more clear, and on the south side of the small elevated area, where "Gorbeck" is written on the six-inch map, what appears to be an outlying patch of the base of the Mountain Limestone is seen resting with a small east-south-easterly dip on the very irregular jagged edges of Silurian rocks dipping 50°, S. 25° W. The surface of the older rocks does sometimes appear to have been weathered, as we see similar rocks weathered in a river bed, and this is what might have been expected from our finding parts of the surface scooped out into small troughs, or even cut down into deep valleys, while on the wide, gently undulating plateaux we find the surface planed off and all jagged edges removed.

I would now call special attention to some interesting points which want working out. First, there is, even within this small district, a different character in the basement deposits of different areas. For instance, in the northern part of Chapel-le-dale there is, as I have shown, a black limestone seen associated with it on both sides of the valley. Now black limestones have a meaning. They are like danger signals telling us to look out for some change. Here is one as the Carboniferous sea is encroaching. There is another which, to enable people to find it, we may call the Hunt Pot Limestone. It occurs at the top of the Mountain Limestone just before it is giving way to the change of conditions which ushered in the Yoredale rocks. There is another on top of Simon's Fell, just above the last good limestone of the Yoredale rocks, when the vast sediments of the Millstone Grit and Coal Measures are coming on, in which there is hardly a trace of limestone, save some poor little beds known as Crow Limestone in the Millstone Grit Series.

The two upper black limestones which I have mentioned are very interesting palæontologically. In the Hunt Pot Limestone the *Producta gigantea* is abundant, with a well-marked elongated variety, ? *P. latissimus*, which is said to mark higher horizons further north.* It is seen no more till we get up to the top of the Upper Scar Limestone on Simon's Fell, where another development of *P. gigantea* is found, with an elongated variety, *P. Edelburgensis*, considered to be specifically different from that found at Hunt Pot.

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* See Garwood and Marr, Geol. Mag., 1895, p. 551.

What are the distinctive fossils of the God's Bridge black limestone? Why is it black? Is it derived from plants which grew on the adjoining land? Or is the carbonaceous matter derived from seaweeds which must have grown on what would correspond to our laminarian zone, or is it, as some hold in the case of the Kimeridge Coal, of animal origin?

Next we notice that the quartz pebbles are far more numerous and occur throughout a greater thickness of limestone over the south-western part of the district, and that sometimes the quartz occurs in subangular fragments. If we were to collect thousands of them where weathered out, could we classify them according to the degree of translucency or crystallisation, or anything that might help us to identify the quartz if we met with it in veins beyond the region now covered by Carboniferous rocks.

The fragments of schists and sandstone also vary in size, manner of occurrence, colour of matrix, &c. Can we make out in each area the proportion of those derived from the immediately underlying rock to those derived from some way off, and can we, from what we have inferred as to the direction of the folds in the pre-Carboniferous rocks (see vol. xiv., p. 332; vol. xv., p. 358; and the consequent position of the outcrops, form some idea as to the drift of the agent which transported them? In this connection let us observe the manner of occurrence of the corals in the basement conglomerates. They must have grown on the large boulders wedged in together wherever there was a small hollow to catch and hold them. But there were some strong currents now and then which tore them out, for we often find the large compound corals broken off, turned over, and buried in the coarse transported shingle. Yet the long, tapering calyx of *Zaphrentis* or *Amplexus* cannot have been generally exposed to sand and pebbles travelling by, and a great cauliflower-like mass of *Lithostrotion basaltiforme*, one or two feet across, would soon show clear marks of what it had gone through had it been rolled into its present position with the well-worn boulders and pebbles of the underlying rocks.

We want, also, to get more evidence as to the remains of placoid fish found in the lower part of one of these pockets under the western precipices of Moughton. These are found in the lowest part of the Carboniferous of Belgium and the South-west of England; and under Moughton occur in the geological equivalent of the beds which were being laid down in Belgium, while the floor on which Ingleborough has been built up was still only the shallow shore of the advancing Devono-Carboniferous sea.

De Koninck and Lohest say with regard to this:—" Il s'ensuiverait que les nombreuses couches qui existent en Belgique entre la zone à *Chonetes papilionacea* et le Devonien supérieur seraient en partie représentées aux environs d'Ingleborough par quelques dizaines de mètres de conglomérats, base du Mountain Limestone."

If these few fossils suggest so much we may hope that diligent search may be rewarded with further results. But the all-important point is this, that every zone in every separate exposure must be separately studied and the fossils of every zone in each locality carefully labelled in the field and kept apart with proper references to sections and maps.

TABLE OF FISH REMAINS, WITH THEIR STRATIGRAPHICAL DISTRIBUTION.*

	LOWER COAL MEASURES.										MIDDLE COAL MEASURES.								
	Halifax Soft Bed	Halifax Hard Bed	Halifax [illegible] Bed	Low Moor Better Bed	Low Moor Black Bed	Low Moor [illegible] above Black Bed	[illegible]	[illegible]	[illegible]	[illegible]	Middleton Main	[illegible]	[illegible]	[illegible]	Thick Coal, Barnsley	[illegible]	Kent Thick Bed, Barnsley	[illegible]	[illegible]
SUB-CLASS ELASMOBRANCHII.																			
Genus *Pleuracanthus*.																			
Sp. *P. laevissimus*, Agassiz																			
P. robustus, Davis																			
P. cylindricus, Agassiz																			
P. alatus, Davis																			
P. alternidentatus, Davis																			
P. tenuis, Davis																			
P. denticulatus, Davis																			
P. Wardi, Davis?																			
P. horridus, Traquair																			
Genus *Diplodus*.																			
Sp. *D. gibbosus*, Agassiz																			
D. tenuis, A. S. Woodward																			
Genus *Cladodus*.																			
Sp. *C. mirabilis*, Agassiz																			
Genus *Janassa*.																			
Sp. *J. linguaeformis*, Atthey																			
J. clavata, McCoy																			
J. sulcatus, Wellburn																			
Genus *Petalodus*.																			
Sp. *P. hastingsae*, McCoy																			
P. ornatus, Wellburn																			
Genus *Ctenoptychius*.																			
Sp. *C. apicalis*, Agassiz																			
Genus *Callopristodus*.																			
Sp. *C. pectinatus*, Agassiz																			
Genus *Helodus*.																			
Sp. *H. [illegible]*, Agassiz																			
H. sp.?																			
Genus *Pleuroplax*.																			
Sp. *P. Attheyi*, W. J. Barkas																			
P. Rankinei, Hanck. & Atthey																			
Genus *Sphenacanthus*.																			
Sp. *S. hybodoides*, Egerton																			
S. aequistriatus, Davis																			
S. minor, Davis																			
S. horridus, Wellburn																			
Genus *Acanthodes*.																			
Sp. *A. Wardi*, Egerton																			
A. major, Davis																			
Genus *Acanthodopsis*.																			
Sp. *A. Wardi*, Hanck. & Atthey																			
ICHTHYODORULITES.																			
Genus *Homacanthus*.																			
Sp. *H. microdus*, McCoy																			
Genus *Hoplonchus*.																			
Sp. *H. elegans*, Davis																			
Genus *Ostracanthus*.																			
Sp. *O. dilatus*, Davis																			
Genus *Gyracanthus*.																			
Sp. *G. formosus*, Agassiz																			
Genus *Lepracanthus*.																			
Sp. *L. colei*, Owen																			
L. rectus, Wellburn																			
Genus *Euctenius*.																			
Sp. *E. unilateralis*, W. J. Barkas																			
Incertæ Sedis.																			
Stemmatodus																			
SUB-CLASS DIPNOI.																			
Genus *Ctenodus*.																			
Sp. *C. cristatus*, Agassiz																			
Genus *Sagenodus*.																			
Sp. *C. inaequalis*, Owen																			
SUB-CLASS TELEOSTOMI.																			
Genus *Rhizodopsis*.																			
Sp. *R. sauroides*, Williamson																			
Genus *Strepsodus*.																			
Sp. *S. sauroides*, Binney																			
S. sulcidens, Hanck. & Atthey																			
Genus *Megalichthys*.																			
Sp. *M. Hibberti*, Agassiz																			
M. intermedius, A. S. Woodward																			
M. pygmaeus, Traquair																			
M. coccolepis, Young																			
Genus *Coelacanthus*.																			
Sp. *C. tingleyensis*, Davis																			
C. elegans, Newberry																			
C. Phillipsi, Agassiz																			
C. elongatus, Huxley																			
C. robustus, Newberry																			
C. granulostriatus, Wellbn.																			
C. [illegible], Wellbn.																			
C. tuberculatus, Wellbn.																			
C. spinatus, Wellbn.																			
C. corrugatus, Wellbn.																			
C. Woodwardi, Wellbn.																			
Genus *Acrolepis*.																			
Sp. *A. Hopkinsi*, McCoy																			
Genus *Elonichthys*.																			
Sp. *E. Aitkeni*, Traquair																			
E. Egertoni, Agassiz																			
E. semistriatus, Traquair																			
E. caudalis, Traquair																			
E. oblongus, Traquair																			
E. Woodwardi, Wellbn.																			
Genus *Rhadinichthys*.																			
Sp. *R. monensis*, Egerton																			
R. Planti, Traquair																			
R. Handcocki, W. & Sherborn																			
R. macrodon, Traquair																			
Genus *Gonatodus*.																			
Sp. *G.* (*Molyneuxi*, Traquair?)																			
Genus *Cycloptychius*.																			
Sp. *C. [illegible]*, Young																			
Genus *M[illegible]*.																			
Sp. *M. Wardi*, Young																			
M. scalaris, Young																			
Genus *Cheirodus*.																			
Sp. *C. granulosus*, Young																			
C. striatus, Hanck. & Atthey																			
Genus *Platysomus*.																			
Sp. *P. Fosteri*, Hanck. & Atthey																			
P. [illegible], Williamson																			
P. [illegible], Traquair																			
P. sp.																			

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* See Davis, J. W., Quart. Journ. Geol. Soc., vol. xxxii., p. 332, 1876.
Wellburn, Brit. Assoc., 1900.
Do. Proc. Yorks. Geol. Soc., New Series, vol. xiv., pt. ii., pp. 150-174, 1901

A LIST OF THE FOSSIL FISHES OF THE CARBONIFEROUS ROCKS OF YORKSHIRE, WITH THEIR DISTRIBUTION.

BY EDGAR D. WELLBURN, L.R.C.P.E., F.G.S., ETC.

The Carboniferous rocks, as found in Yorkshire, comprise the Coal Measures, Millstone Grits, Pendleside Series and Carboniferous Limestone. In the latter group of rocks I include the Yoredale Rocks (Phillips) of North-West Yorkshire.

In the Coal Measures no fish remains have been found in the Upper Measures, as far as I know, but the yield from the Middle and Lower Measures has in the past been plentiful; at the present time, however, specimens are very difficult to obtain, as at most of the pits very little shale (in which the fish remains are mostly found) is brought up to the surface.

In the Millstone Grits and Pendleside Series fish remains are—with very few exceptions—rare.

Again, in the Carboniferous Limestone, the yield of these remains is now very poor, although in the past large collections have been made, notably by Mr. Horne, F.G.S., of Leyburn. His specimens were mostly collected from the Main Cherts or Red Beds at Harmby Quarry, near Leyburn Railway Station. A few others have been found in the Crow Limestone above, and the Underset Limestone below. Others have been found at Richmond, Settle, and Pateley Bridge; though in these localities they are rare.

NOTE.—Since writing this paper. the writer finds that fish remains have been found by Mr. H. Culpin, of Doncaster, in the Upper Coal Measures. These the writer hopes to have an opportunity of describing later.

TABLE OF FISH REMAINS, WITH THEIR DISTRIBUTION IN THE CARBONIFEROUS LIMESTONES. A.

	Wensleydale—Leyburn.	Pateley Bridge	Settle.	Richmond.
SUB-CLASS ELASMOBRANCHII.				
Genus *Cladodus.*				
Sp. *C. mirabilis*, Agassiz	*	...	...	*
C. striatus, Agassiz	*	...	...	*
Genus *Dicrenodus.*				
Sp. *D. dentatus* (McCoy), A. S. Woodward	*	*	...	...
Genus *Janassa.*				
Sp. *J. clavata* (McCoy), A. S. Woodward	...	...	...	*
Genus *Petalodus.*				
Sp. *P. acuminatus*, R. Owen	*	...	*	*
P. Hastingsiæ (McCoy)	*	...	...	..
P. flabellula, A. S. Woodward ...	*	...	...	...
P. lamelliformis? Davis	*	...	...	...
Genus *Petalorhynchus.*				
Sp. *P. psittacinus* (McCoy), Morris and Roberts	*	...	...	...
P. acutus? Davis	*	...	...	...
Genus *Ctenoptychius.*				
Sp. *C. lobatus* (Etheridge), A. S. Woodward	*	...	...	...
C. tripartitus (Davis), A. S. Woodward	*	...	...	...
Genus *Polyrhizodus.*				
Sp. *P. colei*, Davis	*	...	...	...
Genus *Pristodus.*				
Sp. *P. falcatus*, Davis	*	...	..	*
P. concinnus (Davis), Traquair ...	...	...	...	*
P. beuraici (R. Etheridge), Traquair	...	...	...	*
Genus *Copodus.*				
Sp. *C. prototypus* (Davis), A. S. Woodward	*	...	...	...
C. cornuatus, J. Morris and Roberts	*	...	...	*
Genus *Psamodus.*				
Sp. *P. rugosus*, Agassiz	*	...	...	...
P. expansus (Davis), A. S. Woodward	*	..	...	..

TABLE OF FISH REMAINS, WITH THEIR DISTRIBUTION IN THE CARBONIFEROUS LIMESTONES—*continued.* B.

	Wensleydale—Leyburn.	Pateley Bridge.	Settle.	Richmond.
Genus *Helodus.*				
Sp. *H. reticulatus?* Davis	*	...	...	...
H. angularis, Davis	*	...	...	...
H. conicus, Davis	*	...	...	...
H. levis, Davis	*	...	...	...
H. bifurcatus, Davis	*	...	...	...
H. gibberulus (Agassiz), Davis	*	...	*	*
Genus *Venustodus.*				
Sp. *V. serratulus* (Davis), A. S. Woodward	*	...	...	...
Genus *Pleuroplax.*				
Sp. *P. Woodi*, Davis	*	...	...	...
Genus *Pœphodus.*				
Sp. *P. magnus*, McCoy.	*	...	...	...
Genus *Sandalodus.*				
Sp. *S. minor*, Davis	*	...	...	...
Genus *Pœcilodus.*				
Sp. *P. Jonesii*, McCoy	*	...	...	*
Genus *Cochliodus.*				
Sp. *C. contortus*, Agassiz	*	...	...	...
Genus *Deltoptychius.*				
Sp. *D. acuta* (McCoy), Morris and Roberts	*	...	...	...
Genus *Diplacodus.*				
Sp. *D. bulboides*, Davis	*	...	...	...
Genus *Cyrtonodus.*				
Sp. *C. Hornei*, A. S. Woodward	*	...	...	*
C. gibbosus, Davis	*	...	...	...
Genus *Orodus.*				
Sp. *O. moniliformis*, Davis	*	...	...	*
Genus *Diclitodus.*				
Sp. *D. scitulus*, Davis	*	...	...	*

TABLE OF FISH REMAINS, WITH THEIR DISTRIBUTION IN THE CARBONIFEROUS LIMESTONES*—*continued.* C.

	Wensleydale, Layburn.	Pateley Bridge.	Settle.	Richmond.
ICHTHYOÆORULITES.				
Genus *Erismacanthus.* Sp. *E. Jonesi*, McCoy	*	...	...	...
Genus *Physonemus.* Sp. *P. hamatus*, Agassiz	*	...	...	...
Genus *Comphacanthus?* Sp. *C. acutus?* Davis	*	...	...	...
INCERTŒ-SEDIS.				
Genus *Echinodus.* Sp. *E. paradoxus*, Davis	*	...	...	...
SUB-CLASS TELEOSTOMI.				
Genus *megalichthys.* Sp. *M. Hibberti*, Agassiz	*	...	...	...
Genus *Elonichthys.* Sp. *E. Aitkeni*, Traquair	*	...	...	...
Genus *Cheirodus.* Sp. *C.* sp. ?	*	...	...	*

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* Davis, J. W., Trans. Royal Dublin Soc., vol. i., ser. D., 1883.
Do. Quart. Journ. Geol. Soc., xl., 1883.
Wellburn, Proc. Yorks. Geol. Soc., vol. xv., pt. iii., 1905.

TABLE OF FISH REMAINS WITH THEIR DISTRIBUTION IN THE MILLSTONE GRIT ROCKS.*

	D Shales, Mid Grits, Wadsworth Moor.	D Shales, Mid Grits, Marsden.	D Shales Mid Grits, BoulderClough, Halifax.	D Shales, Mid Grits, Kiln House Wood, nr. Halifax.	D Shales, Mid Grits, Ivy Clough, nr. Halifax.	D Shales, Mid Grits, Halifax.	D Shales, Mid Grits, Eccup, nr. Leeds.	D Shales, Mid Grits, Halifax.	C Shales, Mid Grits, nr. Halifax.	Rough Rock, nr. Halifax.
SUB-CLASS ELASMOBRANCHII.										
Genus *Cladodus.*										
Sp. *C. mirabilis*, Agassiz	*	...	...	...	..	...	...	...	...	...
Genus *Acanthodes.*										
Sp. *A. Wardi*, Egerton	*	?	*	*	*	*	*	...	...	...
A. sp.?	...	*	...	...	...	...	...	...	...	...
Genus *Marsdenius.*										
Sp. *M. summiti*, Wellburn	...	*	...	...	...	...	...	...	...	...
ICHTHYODORULITES.										
Genus *Ctenacanthus.*										
Sp. *C. major*, Agassiz	...	*	...	...	...	...	...	...	..	..
Genus *Oracanthus.*										
Sp. *O. Milleri*, Agassiz	...	*	...	...	...	...	..	...	...	...
SUB-CLASS TELEOSTOMI.										
Genus *Strepsodus.*										
Sp. *S. sulcidens*, Handcock & Atthey	*	...	...	..	...	...	...	...	...	...
S. sauroides, Binney	...	*	...	...	...	...	...	...	...	...
Genus *Rhizodopsis.*										
Sp. *R. sauroides*, Williamson	...	*	...	...	...	...	...	...	...	...
Genus *Rhadinichthys.*										
Sp. *R. monensis*, Egerton	...	...	...	...	*	*	...	...	...	...
Genus *Elonichthys.*										
Sp. *E. Aitkeni*, Traquair	*	*	...	...	*	*	...	*	*	*
E. obliquus, Wellburn	*	*	...	...	*	...	...	...	...	...
Genus *Acrolepis.*										
Sp. *A. Hopkinsi*, McCoy	*	...	...	...	*	...	*	...	...	...

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* See Barnes & Holroyd, Trans. Manchester Geol. Soc., vol. xxv., pt. vii., 1897.
Wellburn, Proc. Yorks. Geol. Soc., vol. xiii., pt. iv., pp. 395-399, 1889.
Do. British Assoc., 1900, and Geol. Mag., Dec. iv., vol. viii., No. 443, p. 216, May, 1901.
Do. Proc. Yorks. Geol. Soc., vol. iv., pt. ii., pp. 70-78, 1902.
Do. Proc. Yorks. Geol. Soc., vol. xv., pt. i., 1903.

TABLE OF FISH REMAINS WITH THEIR DISTRIBUTION IN THE PENDLESIDE LIMESTONES.*

	Pule Hill, Marsden.	Crimsworth Dean, near Hebden Bridge.	Whitewell, near Clitheroe.	Todmorden.	Burnsall and Thorpe Fell.
SUB-CLASS ELASMOBRANCHII.					
Genus *Cladodus*.					
Sp. *C. mirabilis*, Agassiz	...	*	...	...	...
C. sp.?	...	...	...	...	*
Genus *Orodus*.					
Sp. *O. elongatus*, Davis	*	*	...	...	...
Genus *Acanthodes*.					
Sp. *A.* sp.?	*	...	...	...	...
Genus *Marsdenius*.					
Sp. *M. summiti*, Wellburn	*	...	...	...	...
M. acuta, Wellburn	*	...	...	...	...
M. sp.?	*	...	...	...	...
SUB-CLASS TELESTOMI.					
Genus *Strepsodus*.					
Sp. *S. sauroides*, Binney	*	...	...	...	...
Genus *Rhizodopis*.					
Sp. *R. sauroides*, Williamson	*	...	...	...	...
Genus *Elonichthys*.					
Sp. *E. Aitkeni*, Traquair	*	*	...	...	...
E. obliquus, Wellburn	*	...	...	*	...
E. sp.?	*	...	...	...	...
Genus *Acrolepis*.					
Sp. *A. Hopkinsi*, McCoy	*	*	...	...	...
Genus *Platysomus*.					
Sp. *P.* sp.?	...	...	*	...	...

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* Wellburn, Proc. Yorks. Geol. Soc., Vol. XIV., p. 111, 1902.
Do. Report to Zone Committee, Brit. Assocn., 1902.

HONORARY SECRETARY'S REPORT, 1906.

The unusual prevalence of fine weather this year has made field work very delightful, and the success of the Society's Meetings and Excursions has been unusually marked. The interesting investigations of the Lower Carboniferous rocks in Nidderdale and North Derbyshire have stimulated the wider examination of these rocks in Yorkshire by some of our members, which promises to bear fruit in very interesting and valuable results.

The Spring Meeting was held at Leeds, as usual, and was associated with a Field Excursion to Micklefield and Garforth, under the leadership of Mr. Edwin Hawkesworth. At Garforth a visit was paid to the sand pits, to examine the basement sand of the Permian series, and the unconformity with the underlying Middle Coal Measures. The lime quarries at Micklefield were then visited and the party was shown round by Mr. S. Clough, the Manager.

Some of the members by invitation attended Mr. Henry Crowther's lecture to children of the Leeds Elementary Schools, on "The Wonders of the Sea and Shore."

At the Council Meeting Mr. Joseph Lomas, F.G.S., was appointed Local Secretary for the Liverpool District, and Mr. Albert Wilmore, F.C.S., F.G.S., Local Secretary for the Colne District. Mr. William Simpson, F.G.S., was appointed delegate to the Corresponding Societies' Committee of the British Association for the York Meeting.

The Council had pleasure in reporting that four of the members of our Society had been appointed officers of Section C of the British Association, viz. :—Mr. G. W. Lamplugh, F.R.S., F.G.S., the President, and three of the Secretaries, the Rev. W. Lower Carter, M.A., F.G.S., Mr. Jos. Lomas, F.G.S., and the Rev. W. Johnson, B.A., B.Sc. A report was received of new sections in the Speeton Clay, at Speeton, and of the important results obtained by the investigations of Mr. E. G. Danford. The question of opening the old pits at Knapton, for the examination of the Speeton Clay inland, was considered, and it was decided that efforts should be made to this end.

The General Meeting was held at the Church Institute, Leeds, under the chairmanship of Mr. Joseph Lomas, A.R.C.S., F.G.S. Three new members were elected—Mr. Ernest E. O. Sibson (Stockton-on-Tees), Mr. W. J. Robinson (Leeds), and Mr. Edward Willey (Leeds). A paper was read by Mr. E. E. Gregory on "A Striated Rock-surface on Harden Moor, near Bingley." A paper was read by Mr. Albert Wilmore, F.G.S., F.C.S., on "The Structure of some Craven limestones." The paper was followed by a discussion, in which Professor P. F. Kendall, Mr. Cosmo Johns, and the Chairman took part. The Chairman then gave an address on South African Geology as seen by the members of the British Association, which was illustrated by a fine series of lantern slides.

The second General Meeting was held at Pateley Bridge, and was associated with a Field Excursion for the examination of the Lower Carboniferous beds of Upper Nidderdale, and of Wharfedale about Grassington, under the leadership of Dr. Wheelton Hind and Dr. Arthur Vaughan (Bristol), from April 13th to 17th. The party started on Good Friday morning up Nidderdale, noting by the way a couple of fine terminal moraines that span the valley, the upper of which has been utilised by the Bradford Waterworks in the construction of the dam for their compensation reservoir. This lake forms a charming addition to the scenic beauties of the valley. Near Lofthouse a few minutes were spent at the water-gush by which the Upper Nidd escapes from its underground channel, and some time was spent in Lolley Scar quarry, on the river bank, in which a fine section of the uppermost shales and limestones of the Yoredale beds was exposed, and from which an interesting series of fossils was obtained. By the kind permission of the Waterworks Committee of the Bradford Corporation, the wagonettes were allowed to pass along the new road to Angram. A fine section at Limley by the roadside attracted the attention of the party for some time. Here a complete change from the former quarry was seen, the dark limestones and shales having disappeared, and their place being taken by a massive, white limestone, full of encrinites. Another decided change was found at the Angram trench, where a couple of dark limestones, separated by a shale parting, overlaid a considerable thickness of black shales, the bottom of which was not seen.

At the top of the section, thin limestones and shales, bent and faulted, were overlaid by Millstone Grit, whilst the limestones underlying the shales on either side of the trench were much faulted. On the return journey a careful examination was made of the beds in the dry river-bed between Manchester and Goydon pots, and the dry river-course was followed to Lofthouse, the succession of limestones being carefully examined. At the General Meeting held at the Crown Hotel, Pateley Bridge, under the chairmanship of Dr. Wheelton Hind, Messrs. H. Lofthouse (Harrogate), C. F. Mott, M.A. (Giggleswick), Percy Lund (Bradford), and the Rev. G. Percy H. Frost, M.A. (Bedale), were elected members and Alderman J. T. Simpson, J.P., was elected Local Secretary for Harrogate.

An address on "Life Zones in the Carboniferous rocks of Yorkshire" was given by the Chairman. Until lately very little success had attended attempts to zone the Carboniferous rocks, but the results of Dr. Arthur Vaughan's efforts in the Bristol area had put quite a new complexion on that branch of investigation. In the gorge of the Avon a magnificent section of the Lower Carboniferous rocks was exposed, unfaulted and complete, and from this Dr. Vaughan had been able to secure evidence of definite fossil horizons, which could be traced over wide areas. Passing northwards, however, the lower part of this zonal series was found to be wanting, and all we had in Yorkshire were the upper zones—characterised by *Productus giganteus* for the older geologists and known as visé by the Belgians. Also in Wales Dr. Hind had found that the whole of the lower zones had been cut out. In Yorkshire, for instance, under Thornton Force, Ingleton, on the upturned edges of Coniston Grits, is the basement conglomerate of the Carboniferous: but it contains a fauna characteristic of the higher zones of the Bristol area. Thus the seas in which the lower

Bristol zones were laid down must have lapped round a land area which was submerged later by the sea in which the fauna of the upper zones lived.

In Yorkshire, and the north, these upper beds of the Lower Carboniferous were found in two forms—one, called by Professor Phillips the Yoredale series, which consisted of a series of limestones, comparatively thin, separated by shales, and southwards represented by a great thickness of pure white limestone, which included the same zonal series. Dr. Hind explained this change as due to a great river from the north-east, which spread its muddy sediment over northern England, the fringe of whose delta thinned out south of Settle. At intervals the corals and shells which luxuriated in the clear sea to the south, were able to encroach on the delta in times of lessened sedimentation. Thus the pure limestones of the southern area were forming at the same time as the Yoredales of the northern area. A band of shales and limestones, the Pendleside series, was found stretching east and west, from Pendle Hill, where they attain a thickness of 1,000 feet, across Yorkshire, until hidden by the newer rocks, and reappearing in Belgium and Germany. These would need for their explanation another river, probably flowing from the east.

Dr. Hind's lecture was followed by a valuable discussion, in which reference was made to the interesting results obtained in zoning the Coal Measures of Staffordshire. Certain marine bands and bands containing freshwater shells being found at definite horizons, the position of which enabled mining engineers to calculate with great nicety the position of related coal-seams in a faulted area. Similar bands had been found in the Yorkshire Coal Measures, and it was urged that additional attention should be paid to these zones, which would be of considerable practical use to the mining engineer.

On Saturday, April 14th, the party visited the old limestone quarries on Greenhow Hill, from which a plentiful supply of corals was obtained. Thence the drive was continued to Dibbles Bridge, where similar Yoredale limestones were examined. A traverse was then made across Appletreewick pastures to the end of Troller's Gill, which was ascended and an examination made of its fine section of the white limestone. On the return journey evidences of glacial overflow valleys were pointed out by Professor Kendall.

On the following Monday the members drove to Grassington and visited the well-known knolls of Cracoe, Rylstone, and Thorpe. Special attention was paid to the structure of these knolls in order to test the theory that they were originally separate islets. Much of the evidence seen did not favour this explanation. Large bags of fossils, in beautiful preservation, were obtained.

After dinner, the General Meeting was resumed under the presidency of Dr. Wheelton Hind, when Mr. J. R. R. Wilson, H.M. Inspector of Mines (Leeds), and Mr. Geo. I. Wells (Sheffield) were elected members.

An address was given by Dr. Arthur Vaughan upon the principles on which the "zoning" of the fauna of rocks should be carried out. He said that zoning must always deal with organisms which lived at about the same bathymetrical level. The worker, for instance, must not pass from a fairly deep water organism to a shallow one and back again. That would be bad zoning. Zones once correctly made should give a time-scale with which to measure changes of all sorts, and with which to measure also the rate of evolution. In considering evolution, one had to consider not a particular species, but a group of species which he called a gens. A gens might be described as a conformable series, all possessing certain common specific characteristics, the essential thing being that there should be continuity. Thus a gens might include several genera. Proceeding to consider the laws of the introduction of a gens, Dr. Vaughan pointed out that the appearance of such a group as he indicated was first heralded by a few early forerunners, which, as fossils, were very few and scarce. Then they came on in enormous crowds. That might be called the main entrance of the gens. Then there would be continuous alteration of the structural details, but the general plan of the animal would always remain the same, the variation being considerable in the complication of the structures, which would become more specialised. This was what was known as ana-genesis. But a specialisation which suited an animal for a particular environment would unsuit it for any changed conditions. Hence the worker would find that under changed conditions the gens showed an attempt to return to the former structural arrangement, which was more plastic. That return was called kata-genesis. As a rule it was unable to return to a form which was ready for further modifications, and under these circumstances the animal seemed to use the remaining energy of the race in the way of ornamentation of its exo-skeleton. Thus, one found shells putting on spines and vesicles which were of no particular use, but merely for ornament. Once that process began the extinction of the race was in sight. Then in the passage from one gens to another the worker might find one species possessing the characteristics of another species. The assimilation of two distinct genera took place very slowly until their convergency, when changes took place exceedingly rapidly, and new species were almost immediately produced. That was called saltation. Dr. Vaughan went on to compare the working of these laws with the ordinary laws of evolution—the law of natural selection and of the elimination of the unfit, and the struggle for existence, and to compare them also with Lamarck's theory of the transmission of acquired characteristics and with Weismann's theory.

Thanks were formally expressed to Dr. Vaughan and to the Chairman for their share in the proceedings, and expression was given to the feeling of gratitude that the ideas and work into which they had initiated the members had added greatly to the interest of the excursions, and provided abundant employment for the future.

A vote of thanks was also passed to the Chairman and Engineer of the Bradford Corporation Waterworks Committee for their kind permission to freely examine the Angram sections.

On the following Tuesday the party separated into two sections, one under Dr. Hind's leadership visiting the shell beds in the Millstone Grit at Hampsthwaite and Cayton Gill. The others made an excursion up Merryfield and Brandstone Becks and Burn Gill in search of glacial evidence. Much satisfaction was expressed with the results of the meeting, geologically considered, combined with the advantages of a spell of glorious weather.

The third General Meeting and Field Excursion were held at Helmsley, on May 25th and 26th, for the study of the geology of Ryedale and the adjoining parts of the Hambledon Hills. The members met on Thursday evening, at the Black Swan Hotel, Helmsley, and visited the famous terraces on the banks of the Rye, surrounding the Hall, and continued their walk through the noble woods to the Deer Park. So extensive are these woods that in one severe storm, a few years ago, no less than 20,000 great trees were felled by the hurricane. An inspection was also made of the ruins of the old castle, with its fine keep and double moat. After dinner a conversational meeting was held, at which the programme and other subjects of geological interest were discussed. A letter was received from Mr. A. H. Pawson, F.G.S., narrating the results of visits paid to Vesuvius since the recent eruptions, and accompanied by specimens of the lava, scoriæ, and volcanic dust.

On Friday morning the members took the train to Sinnington, and ascended the fine gorge of the Seven. The road up the dip slope of the Middle Oolites led to Appleton-le-Moor, and soon a grand view was obtained over the Tabular Hills. Above Lastingham the outcrop of the Lower Calcareous Grit is reached, forming a fine escarpment, the underlying Oxford Clay having been deeply cut down by the beck. The contrast between the wide transverse valley, denuded by the subsequent stream running along the escarpment, and the steep-sided gorge formed by the consequent river running down the dip-slope, was very instructive.

The ancient church of Lastingham, with its unique crypt, was examined, during a brief thunderstorm, and the line of the escarpment was then followed to Hutton-le-Hole, whence the homeward route crossed Gouthwaite Dale and Kirkdale. The remainder of the walk to Newton Station was taken in a heavy downpour of rain.

The General Meeting was held under the presidency of Mr. R. T. G. Abbott, F.S.I., of Malton. Mr. William Walker, H.M. Inspector of Mines, Doncaster, was elected a member. A letter was read from the Rev. E. Maule Cole, M.A., F.G.S., regretting his absence and consequent inability to give an address on the geology of the district, on account of sudden family bereavement. An address on "The Glacial and Physical Geology of the District" was then delivered by the Rev. W. Lower Carter, M.A., F.G.S., who commenced by outlining the solid geology of the area north and west of the Vale of Pickering, which consists of a series of beds of the Middle Oolites, dipping gently towards the central valley, and forming a series of tabular hills intersected by deep gorges, several of which are dry, owing to the swallowing of the streams by the underlying limestone. The Vale of Pickering itself is an interesting geological feature, being due to a trough of Kimeridge Clay (Upper Oolite) let down into the Middle and Lower Oolites by two parallel east and west faults, which also have determined the gap of Coxwold and Gilling. The denuding agencies early found out this belt of soft clay and commenced its excavation, which was probably closely connected with the interesting river diversions of the Rye and the Derwent. The lecturer pointed out that the present gorges of the Tees and the Swale at Rokeby and Richmond appeared to be of Glacial Age, the older direct valleys being obstructed by drift. The Ure, also, in glacial times, was diverted from its straight course eastwards and the valley to Bedale choked by large accumulations of drift, whilst the overflowing stream cut a new channel southwards by Masham to West Tanfield. This gorge is an interesting instance of a valley within a valley, the upper and wider portion representing, in all probability, the course of the glacial overflow stream, and the central narrower gorge being due to the cutting of the river since glacial times. The lecturer then described the changes in the course of these rivers since the close of the Chalk Period and outlined the probable stages in the evolution of the Ouse river-system. After a vigorous discussion, a vote of thanks was passed to the Chairman, to the Secretary for his address, and to Messrs. Bowman, Slater, and Aconly for their kind help in arranging and leading the Field Excursions.

On Saturday morning, May 26th, the party drove up Ryedale, visiting first the far-famed ruins of Rievaulx, with the noted terraces and "temples" on the adjoining slopes. The journey was then continued to Hawnby, the tabular structure of the hills, intersected by deep, narrow gorges, being noted and their origin discussed. At Murton Hill a halt was made to visit Peak Scar Gill, a romantic landslip which has revealed a magnificent section of the Lower Limestone. The slipped masses hang on the steep hill slope, apparently in most unstable equilibrium, and form an imposing spectacle. After a long drive along the main ridge of the Hambledon Hills the party descended to view Gormire Lake and Roulston Scar. The mist, unfortunately, obscured the view over the vale of Mowbray. After a brief halt at the Hambledon Hotel the road to Helmsley was resumed, the return route passing the Deer Park, and a good view of the red deer was obtained.

The Autumn Council Meeting was held in the University Buildings, Liverpool, on Saturday, September 8th, and was associated with an excursion to view the famous footprint beds of Storeton, near Birkenhead.

The Hon. Secretary (Rev. W. Lower Carter) announced that, on account of his removal from Mirfield to Birkenhead, he was compelled to resign the offices of Honorary Secretary and Editor of the Proceedings. In his statement he pointed out that the work of the Society had gradually increased and that it might be difficult to get a competent geologist to take over the whole of the duties. He, therefore, suggested that the financial work should be entirely transferred to the Treasurer, and, if necessary, that the posts of Hon. Secretary and Editor of the Proceedings should be held by different persons. After some discussion, and a statement by the Chairman (Rev. C. T. Pratt, M.A.), of the deep regret with which the Council heard of the impending resignation of the Secretary, it was resolved to postpone the consideration of the subject to an adjourned Council Meeting at Leeds, on September 27th.

The issue of the Proceedings, Vol. XVI., part I., was discussed, and after careful consideration it was resolved that the Records of Council Meetings should be omitted in future, but that important matters occurring therein should be incorporated in the Secretary's Report.

The party then crossed the Mersey and went by electric tram to Prenton, whence they walked to the Storeton quarries to view the remarkable slabs covered with footprints of extinct animals. Mr. H. C. Beasley, of Liverpool, described the footprints, which were probably left by animals coming down to a pool of water, and preserved by drifting sand which had filled up the hollows. The original footprints in the marl soon weathered away, but their sand-casts were hard and permanent. A descent was made into the quarry, where Mr. J. Lomas, F.G.S., described the structure of the Keuper of this area and the interesting faults revealed by the quarrying operations. A hearty vote of thanks was passed to the leaders and the owners of the quarry.

The fourth General Meeting and Field Excursion were held, from September 20th to 24th, in Matlock and district, under the leadership of Mr. H. H. Arnold-Bemrose, M.A., F.G.S., of Derby. The party had the advantage of taking up their quarters at Smedley's Hydropathic Establishment, where all arrangements for their comfort were made by Mr. Alfred Sykes, J.P., the Managing Director, who presided.

After dinner on Thursday, April 20th, Mr. Godfrey Bingley gave an exhibition of lantern slides of geological interest, embracing views from the Yorkshire Coast, Helmsley, Nidderdale, Cheddar Cliffs, and Norway, which was much appreciated.

On Friday morning, September 21st, the train to Miller's Dale was taken. Outside the railway station the leader described the chief features of the landscape and then conducted the party to see the upper lava, which is composed of a vesicular and amygdaloidal dolerite, about 100 feet in thickness, decomposing into spheroidal masses. This "toadstone" is covered by thick limestones, which in their turn are overlaid by several hundreds of feet of thin limestones with bands of chert. Following the Wye down stream the party came to a second bed of lava, about

150 feet lower down in the series, highly vesicular and slaggy in places, which is brought up by a small dome which can be plainly seen from the railway. At the junction of Tideswell Dale with Miller's Dale the thin cherty beds are faulted against the upper toadstone and limestones above it. This probably cuts out 100 feet of thick limestone. Tideswell Dale is a narrow limestone gorge which winds according to the two rectangular series of joints in the limestone, and is now almost dry. The old marble quarry was visited, where a good section was seen of an intrusive dolerite, which cuts across the limestone and the lava, and has baked a bed of volcanic mud forming little roughly hexagonal pillars. The basalt also in places takes on a roughly columnar structure. The limestone underneath the intrusive rock has been converted by the heat into a marble. Higher up the dale good sections of the limestone were found by the roadside showing beautifully weathered corals and brachipods, the beds themselves being dislocated by a series of pretty step-faults.

After lunch at Tideswell and inspection of the fine fourteenth century church, the party walked to Litton, examining a quarry on the way, which showed a section of chert beds interbedded with fossiliferous limestone. After passing through the clean little village of Litton, with its large village green newly planted with trees, a visit was paid to an excavation for a tank in connection with the water supply. Here an excellent section of volcanic tuff, regularly bedded, was examined. The time available before the train, on returning to Miller's Dale, was utilised by a walk into Chee Dale, the autumn beauties of which were much admired.

The General Meeting was held on Friday evening, under the chairmanship of Mr. J. Norton Dickons, of Bradford. Mr. James Burnley, Bramhope Hall, was elected a member of the Society.

Mr. H. H. Arnold-Bemrose, F.G.S., then gave an address on "The Geology of the District," illustrated by lantern slides.

In Derbyshire Igneous rocks are found in both the Carboniferous Limestone and Yoredale rocks. There are beds of contemporaneous lava and tuff, with volcanic vents from which these igneous rocks were ejected, and at a much more recent date (probably Eocene) these series of rocks were invaded by intrusive sills of doleritic rock. The lavas are full of steam holes, which are often found filled with crystalline material, which forms almond-shaped bodies (amygdaloids). Under Raven Crag the Carboniferous Limestone is found including small crystals of iron pyrites, and the decomposed upper layer of the tuff contains small crystals of selenite. The limestones seem to have been laid down in shallow water, and the eruptions which gave vent to the lava (toadstone) and the ashes (tuff) were probably submarine. The limestones overlaid by the subsequent intrusive sills are burnt and converted into marble to a depth of ten feet or so. When, however, the sill overlies a lava-flow the underlying limestone is not marmorized. Where the sill lies on a bed of tuff it is baked and a columnar structure is produced. Mr. Bemrose also descibed the route to be covered by Saturday's excursion.

On Saturday the party went by wagonette to Cromford, through the lovely limestone gorge of the Derwent. Willersley Hall, the home of the Arkwrights, and the mills where Sir Richard carried on his celebrated manufacturing processes, were noted with interest. At Cromford Station the Limestone Shales above the main limestone were examined, and then a visit was paid to the Black Rocks. These well-known picturesque rocks form part of an escarpment of the lower or Kinderscout beds of the Millstone Grit. They are fine specimens of grit weathering, one projecting mass in particular resembling a gigantic animal.

The route was continued through Middleton, the neighbourhood of which appears to be honeycombed with lead workings, and on, up the Via Gellia, to Grange Mills, near which several sections in the volcanic rocks of the Carboniferous series were examined. The sections show a couple of volcanic necks, which are the filled-up vents from which the lavas and tuffs were ejected that form the toadstone and ash beds of the neighbourhood. The volcanic ashes lie in a semicircular belt round the necks and are part of the volcanic cone dissected. The bed of limestone immediately above the breccia of the neck is full of ashy fragments, but the beds a little higher up are pure limestone. The relations of the tuffs to the limestones show that the eruptions were submarine. The volcanic necks are found to be traversed by several intrusive dykes.

Ascending Longcliffe a halt was called to examine the remarkable sandpits which occur in the neighbourhood. The sands appear to have been let down into large hollows in the Carboniferous Limestone, and are wonderfully variegated, the colours ranging from pure white through all shades of yellow, salmon, and red to black. Interbedded with the bands are seams of bright red clays, and the whole is capped by 20 or 30 feet of fine laminated clay without stones. In the sands are found occasionally bleached pebbles of hard grit and limestone. These sandpits occupy a series of large pockets or swallow holes in the limestone, extending in a straight line from Brassington for about seven miles.

The party then visited Brassington Rocks, with their fine castellated escarpment, due to the weathering of the dolomitised limestone.

After dinner Mr. Bemrose exhibited a series of lantern slides descriptive of Monday's route.

The Monday's excursion embraced the interesting glacial deposits of the Derwent valley, which near Crich stand at an elevation of about 900 feet and attain the unusual thickness of 90 feet. The glaciation of this region is full of interesting problems, to which Mr. Bemrose has given special consideration, and which possess many features of interest for glacialists from Yorkshire. At the conclusion of the General Meeting very hearty votes of thanks were passed to Mr. Bemrose for his lecture and leadership, to Mr. Bingley for his lantern exhibition, to Mr. Sykes and Mr. Dickons for presiding, and to the Manager of Smedley's for his courtesy and admirable arrangements.

At the adjourned Council Meeting, held at Leeds, on September 27th, it was decided that it would be more convenient to hold the Annual Meeting at Leeds this year, and to associate it with a Field Excursion to Whitwood Colliery, Normanton, under the leadership of Mr. Isaac Hodges.

The Council decided that the List of Members should be issued and bound up with each part of the Proceedings, but not paged, so that it could be omitted in binding if desired.

The circumstances arising out of the Secretary's resignation were considered, when it was decided that the Honorary Secretaryship should be separated from the Editorship of the Proceedings. A ballot was then taken, and as the result it was unanimously resolved to recommend to the Annual Meeting the following names for election :—

Hon. Secretary :—Mr. James H. Howarth, F.G.S.
Treasurer :—Mr. William Simpson, F.G.S.
Auditor :—Mr. F. W. Branson, F.C.S.

Mr. A. R. Dwerryhouse, D.Sc., F.G.S., was unanimously appointed Editor of the Proceedings. A Publication Committee, consisting of Professor P. F. Kendall, Mr. J. W. Stather, and the Rev. W. Lower Carter, was appointed for conference with the Editor as to the publication of papers.

The following resolution was proposed by the Chairman (Mr. Walter Rowley) and carried unanimously :—" That in the interests of the Society the Council receive with great and sincere regret the resignation of the Rev. W. Lower Carter, M.A., F.G.S., and assure him of their grateful appreciation of the eminent services he has rendered to the science of geology, and more especially to this Society, during the 13 years in which he has acted as its Honorary Secretary and Editor of the Proceedings." It was also resolved that the resignation of Mr. Wm. Cash, F.G.S., as Co-editor, be accepted, with best thanks for his services for the past 13 years.

We regret to have to record the loss by decease, since the last Annual Meeting, of three members: Lord Masham, a life member and Vice-President of the Society, Mr. R. Moffat Kerr, of Halifax, and Mr. Richard B. Cragg, of Skipton. Three other names have also been removed from the list owing to resignation. The number of additions to our membership has been unusually large, 26 in all, thus making a net gain of 20 members for the year, and leaving a total membership of 212, which is the highest yet recorded.

The following arrangements are proposed for the General Meetings and Field Excursions in 1907 :—

Colne and District—at Easter. Leader : Mr. A. Wilmore, F.G.S.

The Isle of Man—May or June. Leader : Mr. G. W. Lamplugh, F.R.S.

Pickering and District—September. Leaders : Messrs. J. T. Sewell and L. G. Rowlands.

Annual Meeting at Sheffield early in November.

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Royal Society of Tasmania.
Royal Society of New South Wales.
Australian Museum, Sydney, N.S.W.
Department of Mines, Sydney, N.S.W.
Australian Association for the Advancement of Science, Sydney, N.S.W.
Department of Mines, Adelaide, South Australia.
Geological Society of Australasia, Melbourne, Victoria.
Nova Scotian Institute of Science.
Natural History Society of New Brunswick.
Royal Institution of Cornwall, Truro.
Royal Geological Society of Cornwall, Penzance.
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Cambridge Philosophical Society.
Essex Naturalists' Field Club.
Edinburgh Geological Society.
Geologists' Association, London.
Geological Society of London.
Hertfordshire Natural History Society, Watford.

Leeds Philosophical and Literary Society.
Leeds Geological Association.
Liverpool Geological Society.
Liverpool Geological Association.
Hampshire Field Club.
Hull Geological Society.
Hull Scientific and Field Naturalists' Club.
Manchester Geological Society.
Manchester Geographical Society.
Manchester Literary and Philosophical Society.
North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
Nottingham Naturalists' Society.
Rochdale Literary and Scientific Society.
Southport Society of Natural Science.
Warwickshire Natural History and Topographical Society.
University Library, Cambridge.
University Library, Glasgow.
Bodleian Library, Oxford.
Radcliffe Library, Oxford.
Yorkshire Naturalists' Union.
Yorkshire Philosophical Society, York.
American Philosophical Society, Philadelphia, U.S.A.
American Museum of Natural History, New York, U.S.A.
Academy of Natural Sciences, Philadelphia, U.S.A.
Academy of Sciences, St. Louis, Mo., U.S.A.
Brooklyn Institute of Arts and Sciences, N.Y.
Boston Society of Natural History, Boston, U.S.A.
Rochester Academy of Sciences, Rochester, N.Y.
Kansas University, Lawrence, Kansas.
Wisconsin Geological and Natural History Survey, Madison, Wis., U.S.A.
Geological Survey of Minnesota, Minneapolis, Minn., U.S.A.
California State Mining Bureau, San Francisco.
Chicago Academy of Sciences.
Maryland Geological Survey, Johns Hopkins University, Baltimore, U.S.A.
Museum of Comparative Zoology at Harvard College, Cambridge, Mass.
New York Academy of Sciences, New York.
United States Geological Survey, Washington, D.C.
United States National Museum, Washington, D.C.
Elisha Mitchell Scientific Society, University of N. Carolina, Chapel Hill, U.S.A.

University of California, Berkley, California.
Meriden Scientific Association, Meriden, Conn., U.S.A.
New York State Library, Albany, U.S.A.
Wagner Free Institute of Science, Philadelphia, U.S.A.
Wisconsin Academy of Sciences, Arts, and Letters.
Smithsonian Institution, Washington, D.C.
L'Academie Royale Suedoise des Sciences, Stockholm.
Societé Imperiale Mineralogique de St. Petersburg.
Societé Imperiale des Naturalistes, Moscow.
Comité Geologique de la Russie, St. Petersburg.
Instituto Geologico de Mexico.
Sociedad Cientifica "Antonio Alzate," Mexico City.
Naturhistorischen Hofmuseum, Wien, Austria.
Societé d'Emulation d'Abbeville, Abbeville.
L'Academie Royale des Sciences et des Lettres de Danemark, Copenhague.
Royal University of Norway, Kristiania.
Kaiserliche Leopold-Carol. Deutsche Akademie der Naturforscher, Halle-a-Saale.
Geological Institution, Royal University Library Upsala.
Imperial University of Tokyo, Japan.
Museu Nacional de Rio de Janeiro.

W. Lower Carter.

HONORARY SECRETARY'S REPORT, 1907.

The event of the year has been the loss of the services of the Rev. W. Lower Carter as Honorary Secretary, on his removal to Cheshire, after 13 years devoted and unremitting labour in the interests of the Society.

On the 28th February the members met and dined together at the Hotel Metropole, in Leeds, when a testimonial, subscribed for by 80 members of the Society, was presented to Mr. Carter by Professor Percy F. Kendall, in the unavoidable absence of the President, the Marquis of Ripon.

The testimonial consisted of—

A mahogany writing table.

A petrological microscope.

A cabinet of rock sections.

A gift of furs to Mrs. Carter, in acknowledgment of much assistance rendered to her husband in his work for the Society.

A gift of a geological hammer by Professor Kendall, and

An illuminated address in the following terms :—

> *To the* REV. WILLIAM LOWER CARTER, M.A., F.G.S.
>
> We, the undernamed members of the Yorkshire Geological Society, desire to express to you our keen sense of the loss we one and all sustain in your removal to Birkenhead.
>
> For thirteen years you have filled the position of Honorary Secretary to the Society, and principal Editor of the Proceedings, with great tact, sound judgment, wide knowledge, and untiring devotion.
>
> Your labours have deservedly been attended with much success, and we are glad to recognise that the present satisfactory position of the Society, as regards the number of its members, the work it has accomplished in recent years, and its standing among the Geological Societies of the country, is principally due to your management and to your influence among our leading geologists.

We desire to assure you, not only of our gratitude for your valued services, and of our admiration for your life and character, but also of the sincere personal affection and regard which you have won from the members of the Society.

All the keener, therefore, is our regret at losing you, but we feel assured that those qualities which have endeared you to us will similarly render your life's work invaluable in your new environment.

MEMBERSHIP.

The Society now consists of—

6	Honorary members.
65	Life members.
147	Members subscribing annually.
218	

Twenty new members have been elected during the year, eight members have resigned, two have been struck off for non-payment of subscriptions, two have intimated that their membership will cease with the current year, and five have died, viz. :—

Mr. Chas. E. de Rance, who has been an honorary member since 1892.
Mr. James Burnley, J.P.
Mr. John Wm. Farrar.
Mr. Arthur N. Briggs, and
Mr. James Booth, J.P., F.G.S.

NEW MEMBERS.

The following have been elected members of the Society during the year :—

H. B. Ratcliffe, Exchange Buildings, Bank Street, Bradford.
Chas. Hy. Gott, F.G.S., M.I.C.E., F.R.M.S., 8, Charles Street, Bradford.
F. Tiffany, B.Sc., Engineer's Office, Midland Railway, Derby.
Hy. Ed. P. Ackroyd, Dean House, North Bierley, Bradford.
Joseph Gibson, F.R.M.S., Elmfield, Psalter Lane, Sheffield.

G. W. Roome, B.Sc., F.G.S., 214, Psalter Lane, Sheffield.
Morton, E. Wager, B.Sc. (Lond.), Cragg Road, Mytholmroyd, Yorkshire.
John Gorges Robinson, B.A., J.P., Cragdale, Settle.
Albert Gilligan, B.Sc., The University, Leeds.
W. E. Lindley, Westfield, South Lane, Shortlands, Kent.
Peter Booth, 65, Richmond Avenue, Leeds.
Ernest Hummel, B.Sc., c/o The University, Leeds.
W. J. P. Burton, F.G.S., Friarage Avenue, Northallerton.
E. G. Highfield, B.Sc., 18, Hall Garth, Pickering.
James M. Mitchelson, J.P., The Hall, Pickering.
Matthew Kitchin, c/o H. C. Embleton, Central Bank Chambers, Leeds.
T. E. Brown, Salterforth, *viâ* Colne, Lancashire.
Charles Bradshaw, F.G.S., Public Museum, Sheffield.
F. G. Brooke-Fox, F.G.S., Ringmore Vean, Kingsbridge.
William Ibbotson, 144, Burngreave Road, Sheffield.

EXCURSIONS.

The Excursions have well maintained the high standard of interest which has characterised those of recent years.

The first was to Colne, in Lancashire, for the examination of the Carboniferous Limestone, Pendleside Series, Millstone Grits, Lower Coal Measures, and Glacial Deposits of the district.

The leader was Mr. Albert Wilmore, B.Sc., F.G.S.

The second Excursion was to the Isle of Man for the examination of the Carboniferous Rocks, Manx Slates, and Glacial Drifts of the Island.

The Society were fortunate in securing as leader the services of Mr. G. W. Lamplugh, F.R.S., F.G.S., who surveyed the Island for H.M. Geological Survey.

The third Excursion was to Pickering for the examination of the Glacial Geology and the Tabular Hills of the district.

The leaders were Messrs. J. T. Sewell and Lewis G. Rowland.

These Excursions will be officially reported for the Society's Proceedings by the Hon. Editor, Dr. Dwerryhouse. It is therefore unnecessary to further describe them in this Report.

PAPERS.

The following papers have been read during the year, including those read at the last Annual Meeting :—

"The Carboniferous Cycle," by Walcott Gibson, Esq., F.G.S., of H.M. Geological Survey.

"The Ingletonian Series of West Yorkshire," by R. H. Rastall, Esq., M.A., F.G.S.

"The Structure and Origin of Limestone Knolls," by Albert Wilmore, Esq., B.Sc., F.G.S.

"Dendroid Graptolites in the Carboniferous Rocks of Britain," by Wheelton Hind, Esq., M.D., F.G.S.

"The Carboniferous Rocks of the Isle of Man," by Wheelton Hind, Esq., M.D., F.G.S.

CENTENARY OF THE GEOLOGICAL SOCIETY.

An important event during the year has been the celebration of the Centenary of the Geological Society of London on the 26th to 29th September, 1907.

The Rev. Chas. T. Pratt, M.A., was appointed to represent the Society as delegate, and to present on the Society's behalf the following address :—

> *To the President, Council, and Fellows of the Geological Society of London.*
>
> The members of the Yorkshire Geological Society (founded in 1837 as the Geological and Polytechnic Society of the West Riding of Yorkshire) beg to present their sincere and hearty congratulations on the attainment of the Centenary Anniversary of your Society.
>
> It is with much satisfaction that they recall the names of not a few Yorkshiremen who have held high positions amongst the officers and Council of your Society, and they gladly recognise how great and varied have been the services rendered to Yorkshire Geology by past and present distinguished members of your fellowship.
>
> They desire to offer you their sincere thanks for the constant stimulus and help which your Society has afforded to

local Geological Societies, and the generous way in which local workers have received recognition at your hands.

They would, further, express their sense of the great service rendered to the science of Geology by your Society during the whole period of its existence, and acknowledge the lasting benefits which the labours and researches of your members have conferred on geologists all over the world.

They greatly appreciate the sound judgment which has ever characterised the management of your affairs, your ready welcome to all earnest workers, and your generous encouragement of all effort sincerely designed to advance geological knowledge.

(Signed) RIPON, *President.*
J. H. HOWARTH, *Hon. Secretary.*

EXCHANGES.

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Rochdale Literary and Scientific Society.
Southport Society of Natural Science.
Warwickshire Natural History and Topographical Society.
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Academy of Science, St. Louis, Mo., U.S.A.
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Rochester Academy of Sciences, Rochester, N.Y.
Kansas University, Lawrence, Kansas.
Wisconsin Geological and Natural History Survey, Madison, Wis., U.S.A.
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Museum of Comparative Zoology at Harvard College, Cambridge, Mass.
New York Academy of Sciences, New York.
United States Geological Survey, Washington, D.C.

United States National Museum, Washington, D.C.
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University of California, Berkley, California.
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Smithsonian Institution, Washington, D.C.
L'Academie Royale Suedoise des Sciences, Stockholm.
Societé Imperiale Mineralogique de St. Petersburg.
Societé Imperiale des Naturalistes, Moscow.
Comité Geologique de la Russie, St. Petersburg.
Instituto Geologico de Mexico.
Sociedad Cientifica "Antonio Alzate," Mexico City.
Naturhistorischen Hofmuseum, Wien, Austria.
Societé d'Emulation d'Abbeville, Abbeville.
L'Academie Royale des Sciences et des Lettres de Danemark, Copenhagen.
Royal University of Norway, Kristiania.
Kaiserliche Leopold-Carol. Deutsche Akademie der Naturforscher, Halle-a-Saale.
Geological Institution, Royal University Library, Upsala.
Imperial University of Tokyo, Japan.
Museu Nacional de Rio de Janeiro.

J. H. HOWARTH.

EXCURSIONS, 1907.

The first Excursion of the year was held at Colne, at Easter (March 29th to April 2nd), under the presidency of Mr. Cosmo Johns, F.G.S., M.I.Mech.E., and the leadership of Mr. Albert Wilmore, B.Sc., F.G.S.

The Excursions were held in conjunction with the Liverpool Geological Society, a number of whose members were present under the presidency of Dr. A. R. Dwerryhouse, F.G.S.

The headquarters of the Societies were at the Crown Hotel, the evening meeting being held at the Municipal Technical School, by kind permission of the Committee.

The special object of the meeting was the investigation of the Carboniferous rocks of the area, with special reference to their life zones and to the mode of origin of the limestone knolls which occur in the region round Clitheroe.

On Friday morning, the party left Colne by train for Thornton-in-Craven, whence they walked to Thornton Quarry, where there is an extensive exposure of Carboniferous Limestone with fossiliferous shales. These beds are on the same horizon as those exposed at Clitheroe. Good specimens of the characteristic fossils were obtained, and the party then moved on to South Field Quarry, slightly lower in the series. Here thin-bedded, impure limestones, with many remains of corals, are to be seen.

A thin seam of soft coal occurs near the top of the quarry, resting on a fossiliferous shale of marine origin.

In Rain Hall Quarry the same beds are exposed as in Thornton Quarry. The beds dip at a high angle to the southward.

From a hill close by this quarry a fine view of the rolling outlines of the district was obtained, though the hazy atmosphere prevented a good view of the distant grit hills.

Crossing over the crest of the anticline to Gill Church, the beds were observed dipping to the north, and in the quarry at Gill Rock a small overthrust fault was seen, by which a mass of dark shales had been pushed over on to a mass of limestone.

On the way from Gill Rock to East Marton a boulder of fine-grained Silurian Grit was observed. This had been carried into the district by glacial action and was probably derived from the exposures in Upper Ribblesdale.

After lunch at East Marton, the walk was continued by three small quarries at Broughton Fields to Clints Delf.

In the third of these quarries the bedding is much disturbed by overfolding, while on the south side the beds are vertical.

After a walk over the fields of about one mile, Swindon Moor Quarry was reached, where the limestones were found to be very fossiliferous, many Crinoids being collected. The beds are vertical, or nearly so, and show signs of much faulting.

The whole of these exposures is on the flanks of a great anticlinal fold in the Carboniferous Limestone, running in a south-westerly direction from Skipton to Barnoldswick, where it is cut off by a fault which brings in the Millstone Grit and shifts the limestone outcrop to the north.

The return journey to Elslack was then commenced, exposures in the Pendleside Series being examined *en route*.

Colne was reached by train after a glorious day. The weather had been perfect, the heat of a clear sun being tempered by a refreshing breeze.

The members dined together at the Crown Hotel, Colne, after which they adjourned to the Municipal Technical School, where Mr. Albert Wilmore, B.Sc., F.G.S., read a paper on "The Structure and Origin of Limestone Knolls," which was followed by a discussion (see pp. 158 to 170).

The chair was taken by Mr. Cosmo Johns.

A start was made from Colne at 9 a.m. on Saturday morning, and the members were conveyed by wagonette through Barrowford, Blocko, and by Coldweather Hill to Gisburn, Sawley, Grindleton, and Chatburn.

The route from Colne to Gisburn lies across the strike of the beds, so that the party passed successively across the outcrops of the Lower Coal Measures, the Millstone Grit, the Pendleside Series, and the Carboniferous Limestone.

At Sawley Quarry and Foxley Bank (see Pl. XX.) magnificent examples of folding in the limestone beds were examined.

A drive of about two miles along the strike of the beds and the "reef knoll" country was reached.

Here the party dismounted in order to visit the many quarries, including the celebrated dissected reef knoll at Pimlico Quarries.

The limestone knolls at Downham, Chatburn, and Worston were examined, a visit also being paid to the Salt Hill and Lane Head Quarries. As these exposures are fully described in Mr. Wilmore's paper in the present volume, no further account of them need here be given.

A magnificent view of the knoll country was obtained from the summit of one of these rounded hills. In front lay the town of Clitheroe, with its picturesque church and castle. To the right were the limestone knolls, forming rolling grass-covered hills, with here and there patches of White Limestone showing through, while to the left could be seen the long ridge of Pendle Hill, with its bare brown flanks, gradually passing into the green cultivated lands below.

The homeward journey from Worston was by way of Worston Knoll to Chatburn, where the party rejoined the conveyance and drove through Rimington to Colne.

The weather had again been favourable and a most enjoyable day was spent.

In the evening there was a general discussion of the work done on Friday and Saturday, and several broader questions affecting Carboniferous Geology were also considered.

After dinner on Sunday, as several of the members were leaving the party on Monday, Dr. Wheelton Hind proposed a vote of thanks to Mr. Wilmore for the able manner in which he had arranged and conducted the excursions, remarking upon the very thorough and intimate knowledge of the country he had displayed.

Mr. Wilmore was presented with a copy of the menu signed by those present, and replied in a humorous speech.

Professor Kendall then proposed the health of the visitors, which was responded to by Mr. Carruthers, of H.M. Geological Survey, and Mr. Whitehead, Secretary of the Liverpool Geological Society.

The toast of "The President" (Mr. Cosmo Johns, F.G.S.) was then duly honoured on the proposition of Mr. J. Lomas.

On Monday morning work was resumed, the members travelling by train to Earby.

The limestones and shales of the Pendleside Series were examined in the Salterforth Cutting, and gave rise to considerable difference of opinion.

This series lies immediately below the Millstone Grit in the district to the south of the Great Craven Faults, but is absent from the fells to the north of the faults, e.g., Ingleborough and Fountain's Fell.

The Barnoldswick Fault was then traveresd, and it was seen that the Millstone Grit Series was here thrown down against the Carboniferous Limestone group.

This fault runs for a distance of about nine miles in an approximately north-west to south-east direction, the downthrow being to the south-west.

Another exposure of the Pendlesides was seen at Weets, where the series dips beneath the Pendle Grit. It is necessary to distinguish clearly between the Pendle Grit, which locally forms the base of the Millstone Grit, and the Pendleside Grit, which is at a lower horizon and belongs to the lower group, now known as the Pendleside Series.

A walk of a little more than a mile over the Millstone Grit Fells brought the party to the Moorcock Inn.

In the afternoon the party descended Admergill Brook, where an interesting section of Boulder Clay was examined. This contained, in addition to many fragments of the local grits, well-scratched pebbles of limestone, which must have been derived from the north side of the watershed, together with a Silurian Grit boulder, probably from Ribblesdale or Crummack.

Turning up Pendle Water, which in this part of its course flows along the strike of the beds, fine exposures of the fossiliferous Sabden Shales were met with.

Here Goniatites, *Aviculopecten*, and *Posidoniella* were collected.

These shales lie between the Kinder Scout and Second Grits, and are obviously of marine origin, pointing to a period of salt water (outer estuarine) conditions, an episode in the history of the great Millstone Grit delta.

Pendle Water flows from the slopes of Pendle Hill and is subject to sudden and destructive floods, which have necessitated the erection of considerable training walls.

Remains of plants (*Calamites*) were also found in these shales and many of the goniatites were observed to contain small quantities of petroleum. Some of the members visited the picturesque Hall at Roughlea, the house mentioned by Ainsworth in "The Lancashire Witches."

Following the stream downwards, a charming valley was traversed, and Mr. Wilmore pointed out many matters of interest in connection with the denuding action of the stream, and was able in one case to indicate the amount of material which had been removed during the last 20 years, and to show the two ends of a footpath, the middle part of which has now disappeared.

The observations made during the early part of the day in the railway cutting at Salterforth raised matters of such interest that it was decided to cancel Tuesday's programme, and to visit Winterburn, near Skipton, where beds of similar age are exposed, in the hope that some further light might be thrown upon the question.

On Monday evening there was an interesting exhibition of fossils from the Carboniferous rocks of the district by Mr. Peter Whalley and other local collectors.

Mr. Whalley's collection included a large number of fossil plants from the Coal Measures and a unique collection from the Millstone Grit Shales near Grassington.

On the proposition of Professor Kendall and Mr. Lomas a vote of thanks was passed to the exhibitors.

On Tuesday morning the party proceeded by train to Skipton, and thence drove to Winterburn Valley. Here they succeeded in finding a very good sequence of rocks and many interesting and well-preserved fossils.

Commencing near Winterburn village the thin limestones and shale beds were carefully examined, several interesting shells and corals being found. A very interesting fossil sponge was added to the spoils collected during these Excursions.

The next rocks to be searched were the shales below the Winterburn Reservoir bank, and here again the enthusiasts were quite successful. It was remarked that not once during the whole of the Excursions had the party drawn blank.

The White Limestones seen immediately above the bank of the reservoir were the next to be attacked, and here beautiful fossils in great variety were obtained. The day's work was felt to be complete when the Black Shale beds were found north of this, and were seen to contain the same fossils as the similar Black Shale beds at Weets, near Barnoldswick, which had been examined on the previous day.

On the return to Skipton the party walked along the old moat bank and examined the beautiful sections of folded rocks which are there exposed. From Skipton the members returned to their homes satisfied that they had helped in no small degree the solution of some of the problems presented by the very interesting country which they had seen.

The second Excursion was held in the Isle of Man, from Friday, June 7th, to Tuesday, June 11th, for the purpose of investigating the Carboniferous rocks in the south of the Island, with a view to their correlation with the rocks of the mainland; the Manx Slate Series, and the glacial deposits of the Island.

The Society was particularly fortunate in having as Chairman of the meeting Mr. P. M. C. Kermode, of Ramsey, whose knowledge of the geology, topography, and antiquities of the Island is extensive and thorough.

In the choice of leader of the Excursion the members were no less fortunate. Mr. G. W. Lamplugh, F.R.S., of H.M. Geological Survey, who surveyed the Island some years ago, possesses a knowledge of its geology which could not be surpassed, and to his genial companionship and lucid expositions the success of the expedition was in no small degree due.

When it is stated that Dr. Wheelton Hind was also present, it will not be a matter of surprise that the Excursion was one of the most successful ever held by the Society.

The party left Douglas on Friday morning by train for Ballasalla and walked to the coast at Derby Haven.

On the road, boulders of Foxdale Granite were found, These have been distributed to the south and west of the outcrop, which occurs in the centre of the Island, by glacial action. They have also been carried by the ice to the summit of S. Barrule, at an elevation of 700–800 feet above the highest point of the parent rock. This is one of the best examples of uplift by glacial action in the British Isles.

The first exposure examined on the coast was one of Carboniferous Limestone, the horizon being about 200 feet above the base of that formation. Numerous fossils were collected, with a view to comparing the horizon of these rocks with those of the mainland. Proceeding along the beach, a small fault was crossed and the basement conglomerate of the Carboniferous Series was examined. It consists of a red calcareous matrix, with pebbles of quartz and slate and a few of the dyke materials from the Slate Series.

The beds of the Carboniferous Limestone were then crossed in ascending order, and the members proceeded to Langness, where exposures of the Manx Slate Series were examined.

A move was then made to Fort Island, where the Manx Slates were seen to be penetrated by two series of igneous dykes. The older set was injected prior to the great earth movements which produced the crumpling of the Manx Slates, since the dykes are sheared in the same manner as the slates. The later series of dykes (probably of Tertiary Age) cuts the older series and is not sheared.

On the Castletown side of Langness a series of natural arches has been produced by the action of the sea.

The tops of the arches consist of the basal conglomerate of the Carboniferous Series, while the sides consist of the Manx Slates (see Pl. XVII.).

The Manx Slates formed an island in the Carboniferous Sea as they do now in the Irish Sea, and the shingle beaches produced in that remote period are exposed as these red conglomerates, which can still be seen resting against their old shore platforms. The slates below the conglomerate are stained red for some distance from the junction.

The Carboniferous rocks were again examined on the walk to Castletown, and after lunch Scarlet Point was reached by way of the beach.

The Carboniferous Limestone was again traversed in Castletown Bay, and in the quarry at Scarlet a good suite of fossils was obtained.

From these, and others which were collected during the morning, it was concluded that the whole of the Manx Carboniferous Series belongs to the upper beds and that the lower part of the Carboniferous Limestone of the mainland is unrepresented.

At Scarlet Stack a fine series of volcanic rocks of Carboniferous age is exposed. The Stack of Scarlet was formerly supposed to be the neck of a volcano, but recent researches by Mr. Lamplugh tend to show that the volcanic rocks have been thrust over the Carboniferous Beds, which are themselves considerably contorted (see Pl. XVI.).

The evening meeting was held at the Pevril Hotel.

Dr. Hind read a paper on "Dendroid Graptolites in the Carboniferous Rocks of Britain" (see pp. 155 to 157).

One of the specimens exhibited was found on Pendle Hill, in Yorkshire, the other at Poolvash, in the Isle of Man.

The paper was discussed by Mr. Lamplugh, Rev. W. Lower Carter, and Mr. Bembrose.

Dr. Hind then read a second paper on "The Carboniferous Rocks of the Isle of Man" (see pp. 137 to 154), which was discussed by Messrs. Sibley, Cosmo Johns, Culpin, and Lamplugh.

The Chairman (Mr. P. M. C. Kermode) drew the attention of the members to the formation of a Manx National Museum, and stated that that institution would be glad to receive any specimens which they might wish to bestow.

Mr. Whitaker proposed, and Mr. Pratt seconded, votes of thanks to the Chairman and to the Leader of the Excursions, both of which were heartily passed.

On Saturday morning Castletown was again the starting-point. Here some of the members inspected the Castle by the courtesy of the Governor, and were shown the collections which form the nucleus of the Manx National Museum.

Others proceeded at once to Scarlet Point, where Friday's researches into the relation of the Volcanic Series to the Carboniferous Limestone were resumed.

Passing along Port St. Mary Bay in the direction of Poolvash, the beds of ash and lava were seen to be strongly folded, and in some instances brecciated, blocks of the harder lavas being involved in the soft ashy beds.

On nearing Poolvash the ash beds were found to be less and less contorted, and in some instances to contain fossils.

These were evidently similar to those of the neighbouring limestones, and prove that these ashes were deposited in the form of mud in the Carboniferous Sea and that the volcano which produced these Scarlet beds was active during the Carboniferous Period.

On the cliff is a large quarry in Black Flaggy Limestone, the "Poolvash Marble." With regard to these beds there appears to be little difficulty, since they contain fossils characteristic of the Pendleside Series, and therefore rest on the top of the Carboniferous Limestone.

On the foreshore, however, the Flaggy Limestones are exposed in a number of folds, the surfaces of these somewhat resembling that of an over-turned boat. As one proceeds further along the coast these domes have their summits broken through and a White Limestone with abundance of fossils can be seen through the openings thus produced. On passing still further in the same direction the White Limestones are seen to form a number of knolls, from which the Black Flaggy Beds dip away in all directions.

There was considerable difference of opinion as to the mode of origin of these knolls, and the discussion of them was left over until the evening.

On the way from Poolvash to Port St. Mary a fault was crossed, bringing in the Manx Slate Series.

These rocks, like the beds of similar age on Langness, are contorted and sheared to such an extent that the original bedding planes are almost indistinguishable, and many dykes of Camptonite which they contain are so crushed, sheared, and drawn out as to be almost unrecognisable.

Lastly, the outlier of Carboniferous Limestone at Port St. Mary was visited and found to belong to the same horizon as the beds on the other side of the bay.

On Sunday some of the members visited the coast between Gob-y-Diegan and Peel.

At Gob-y-Diegan fine exposures of the Crush Conglomerates, first described by Mr. Lamplugh, were seen to great advantage, the tide being very low at the time. The lowness of the tide also enabled the members to examine a large series of sea-worn caves at this point.

Nearer Peel, a halt was made to examine the red "Peel Sandstones," which have given rise to so much discussion.

There was some difference of opinion expressed as to the age of these beds, but as no new evidence was forthcoming no definite conclusion was reached.

On Monday morning the party proceeded by electric car to the summit of Snae Fell. The principal object in visiting this point was to obtain a comprehensive view of the structure of the island. Unfortunately this was rendered impossible by a thick cloud which completely covered the summit and blotted out the surrounding landscape. The glacial striæ which occur on the summit were, however, well seen. These, which run athwart the Island from north-west to south-east, are of very great interest as regards the determination of the conditions which obtained during the Glacial Period.

The Isle of Man, occurring as it does in the centre of the Irish Sea, gives the key to the whole question of the glaciation of the Irish Sea Basin.

The fact that Snae Fell is striated across its summit shows that the ice must have been sufficiently thick to completely bury the Island. While the central ridge of the Island was overridden, the lower layers of the ice seem to have swerved round the obstruction and flowed coastwise along both sides of the

Island. The boulders of Scottish rock so common in the drifts of the lowlands are confined to the belt of this coastwise flow, and are not found in the central hill group.

On proceeding down Sulby Glen several exposures were examined, showing the mode of formation of the Crush Conglomerates in the Manx Slate Series. These have been produced by the close folding of the slates, and the consequent breaking up of the thin beds of grit which they contain to form pebbles which are now involved in the slaty matrix. They strongly resemble in general the conglomerates produced by the cementing together of water-worn pebbles, but their origin was made perfectly clear by an examination of the sections seen in the Glen.

The return journey was by rail to Ramsey and on by electric car to Douglas.

On Tuesday the party was considerably diminished in numbers, several members leaving by the early boat.

This, the last day of the Excursion, was devoted to an examination of the glacial deposits in the north of the Island. The northern part of the Island consists of a flat plain extending from the line of the Manx Northern Railway, between Ramsey and Ballaugh, to the Point of Ayre. This plain consists entirely of gravel and Boulder Clay of Glacial Age, the solid rock floor being everywhere below sea level. Thus the pre-glacial coast of the Island must have run along the line of inland cliffs from Ramsey to Ballaugh.

Through Bride and Andreas, and on to Jurby, runs a terminal moraine, the structure of which is well exposed in cliff sections between Marine View and Port Cranstall.

Between this moraine and the old cliff line lies an area covered with peat and known as the Curragh.

Between this and the moraine are several terraces of gravel, probably deposited by the flood-waters flowing from the ice-front through gaps in the moraine.

On reaching Ramsey, members drove to Sea View, where they left the conveyances and proceeded along the beach examining the cliffs *en route*.

A number of fossil shells were collected from the glacial beds. These evidently belonged to several different periods, some being warm and some cold water species, and probably reached their present position in the same manner as the boulders which accompany them, being dragged up from the sea floor by the movement of the glacier. The boulders found in these beds include many rocks of Scottish origin, including the granites of Criffel and Dalbeattie, grits from the Ordovician, of the South of Scotland, and notably the fine grained granite of Ailsa Craig; also flints, probably derived from the chalk of Antrim.

The conveyances were rejoined at Port Cranstall, and after a short drive over a raised beach the Point of Ayre was reached.

Here the members were allowed to examine the cores of a deep boring which is being put down in search of coal at the extreme north point of the Island. The boring up to the present has been for the most part in rocks of Triassic Age.

The return journey was by way of Bride, where Mr. Kermode described some interesting Runic crosses which are preserved in the churchyard, and thence to Sulby Glen Station, an opportunity of examining the old course of the Sulby River being afforded on the way.

This brought the work of an extremely interesting Excursion to a close. In spite of somewhat unfavourable weather the meeting was a most enjoyable one.

The Autumn Meeting was held in the district surrounding the ancient town of Pickering.

The President for the meeting was James M. Mitchelson, Esq., J.P., of Pickering, and the leadership of the Field Excursions was undertaken by Messrs. J. T. Sewell and Lewis G. Rowland.

The headquarters of the Society were at the Black Swan Hotel, Pickering, and a considerable number of members had already arrived on Thursday evening, while others joined the party on Friday.

On Friday morning the members left the Black Swan at nine o'clock and drove by way of the village of Lockton to the Hole of Horcum, where a halt was made to examine the remarkable configuration of the ground at this point.

The first part of the drive lay through a rich agricultural district, where harvesting operations were in full swing, but later the open moorland, covered with heather and bracken, was reached.

The moorland is intersected by numerous deep valleys, with extremely steep sides and in many instances well wooded, forming a pleasing contrast to the open moorland above.

The Hole of Horcum is a cirque-like depression some 400 feet in depth, which is separated from the Saltersgate Valley by a very narrow ridge of rock.

The hollow is excavated in the Oxford Clay, the upper part of the slope being formed by the Lower Calcareous Grit. Many springs issue from the sides of the valley along the line of junction of the two rocks, and the erosion caused by these wearing away the softer rock, and the consequent falling down of the hard rock above, is probably responsible for the very unusual form of the valley.

Crossing the watershed, a sharp topped ridge, not 50 yards wide, and which carries the main road from Pickering to Whitby, a fine view of the Saltersgate Valley and of Newton Dale was obtained.

It seems probable that the Saltersgate stream formed the head waters of a river which, in pre-glacial times, flowed northwards into the Esk, along the line of the present Newton Dale. To-day, the stream, on falling into Newton Dale, turns sharply to the southward, and flows into the Derwent drainage.

The direction of flow of these waters was reversed during the Glacial Period, the watershed having been cut through by the overflow from a glacier-dammed lake in the north.

In the neighbourhood of Saltersgate the bracken was already brown owing to the early frost. On the 1st September the district was visited by a sharp frost, and it is reported that on the night of the 1st a water tap in the village of Goathland was frozen.

A small excavation in a sandy bed of the Oxford Clay Series was examined near Saltersgate, and a few indistinct plant remains were found.

Near the junction of the tributary valley with Newton Dale, the stream forms a picturesque waterfall at the point where it passes over the Kellaways Rock, a hard sandy bed at the base of the Oxford Clay.

About 100 yards below the fall there is a fine mass of tufa, formed by the evaporation of the waters, charged with carbonate of lime, of a small spring which issues from the side of the gorge.

Passing further down the valley, Newton Dale was reached and the railway crossed, and lunch was consumed at the Needle's Eye, whence there are fine views over the moors and along Newton Dale in both directions.

A walk of about two miles over the heather then brought the party to Seavey Slack, where there is a channel through the moorland which is believed to be the overflow of a glacial lake.

The party was particularly favoured by the remarkably dry condition of the moor and the shortness of the heather.

From Seavey Slack the route again lay across the moors to Stape, where the conveyances were waiting to convey the members back to Pickering.

On the homeward journey the party was met by Mr. Mitchelson, who conducted the members to the Roman camps at Cawthorn. Magnificent views of the surrounding country were obtained from various points on the route, and the headquarters were reached at 6.30.

The General Meeting was held at the Black Swan Hotel, Pickering, on Friday evening, under the presidency of Major Mitchelson, J.P.

Seven new members were elected. The Chairman gave an interesting address dealing with some lake-dwellings which he discovered some years ago on the shores of the now dry Lake Pickering.

The dwellings were built on piles, and appear to have been connected with islands in the lake by means of trestle bridges. It was not possible to determine, from the somewhat scanty remains of these bridges, whether or not there were any arrangements for cutting off communication with the shore in case of attack. Much pottery was found, together with the remains of very large, and now probably extinct, deer, and some human bones.

In speaking on the address, Professor Kendall called attention to the close connection between Geology and Archæology, and thanked the President for his interesting address.

Mr. J. W. Stather opened a discussion on certain beds of gravel which occur along the western foot of the Wolds, and whose age and relationships have not yet been determined. He suggested that the Society should take an early opportunity of visiting the South Cave district, where the various beds of gravel are well exposed.

The discussion was continued by Mr. Wm. Simpson and Professor Kendall, who heartily supported the suggestion that a Field Meeting should be held at South Cave.

On Saturday morning the members drove by the village of Lockton to a farmhouse near the Bride Stones. These are curious masses of hard calcareous sandstone which stand out on the hillside and form a conspicuous feature.

From this point the party divided, the main party going by way of Jackdaw Griff to the village of Levisham and thence by way of Levisham Station to Newton. The others went by way of the Hole of Horcum to Newton, where the conveyances were waiting to convey them back to Pickering. *En route*, the large quarries in the Corallian, close to Pickering, were visited, and a number of fossils were obtained.

It is a matter of congratulation that two out of the three Excursions held during the current year have resulted in original papers on the districts visited, and it is to be hoped that in future districts may be chosen in which definite problems await solution, and that the energies of the members may, as was the case in the Colne and Isle of Man Excursions, be directed towards the elucidation of such problems.

ARTHUR R. DWERRYHOUSE.

THE YORKSHIRE GEOLOGICAL SOCIETY.

Statement of Receipts and Expenditure, November 1st, 1905, to November 1st, 1906.

REVENUE ACCOUNT.

Dr.

1905.		Receipts.	£	s.	d.
Nov.	1	To Balance in Bank	0	5	9
1906.					
Nov.	1	,, Life Member's Subscription transferred from Capital A/c	6	6	0
		,, Members' Annual Subscriptions	80	12	0
		,, Sale of Proceedings	9	6	0
		,, Halifax Corporation, Interest on Mortgage Bond	11	12	10
		,, Balance owing to Bank	17	4	3
			£125	6	10

Cr.

1906.		Expenditure.	£	s.	d.
Nov.	1	By Cost of Proceedings (Chorley & Pickersgill, Ltd.)	70	9	3
		,, Stamps for Proceedings	3	9	8
		,, Sundry Printing, Stationery, Circulars, &c.	12	6	4
		,, Meetings and Excursions	12	14	9
		,, Hon. Secretary's Postages and Petty Cash...	16	8	8
		,, Jackson, Maps	2	9	2
		,, Stanford, Maps and Memoirs...	7	9	0
			£125	6	10

CAPITAL ACCOUNT.

1906.			£	s.	d.
Nov.	1	To Halifax Corporation Mortgage Bond ...	350	0	0
		,, One Life Member's Subscription	6	6	0
			£356	6	0

1906.			£	s.	d.
Nov.	1	By Transfer to Revenue A/c	6	6	0
		,, Balance, Halifax Corporation Mortgage Bond	350	0	0
			£356	6	0

Halifax, November 1st, 1906.

Audited, compared with Vouchers, and found correct,
WM. SIMPSON, *Hon. Auditor.*

J. H. HOWARTH,
Hon. Treasurer.

THE YORKSHIRE GEOLOGICAL SOCIETY.

Statement of Receipts and Expenditure, November 1st, 1906, to November 1st, 1907.

REVENUE ACCOUNT.

Dr.

1907.	Receipts.	£	s.	d.
Oct. 31	To Life Members' Subscriptions, transferred from Capital A/c.	8	18	0
	,, Members' Annual Subscriptions	105	6	0
	,, Sales of Proceedings	9	17	9
	,, Halifax Corporation, Interest on Mortgage Bond	11	12	10
	,, Income Tax Recovered	1	12	5
		£137	7	0

Cr.

1906.	Expenditure.	£	s.	d.
Oct. 31	By Balance owing to Bank	17	4	3
	,, Cost of Proceedings (Chorley & Pickersgill, Ltd.)	69	5	5
	,, Sundry Printing, Stationery, Circulars, &c.	13	5	0
	,, Meetings and Excursions	12	16	3
	,, Hon. Secretary's Postages and Petty Cash	6	18	0
	,, ,, Treasurer's ,, ,, ,, ,,	1	9	2
	,, Stanford, Maps	0	17	6
	,, Balance in Bank, less Cheque not yet presented	15	11	5
		£137	7	0

CAPITAL ACCOUNT.

1907.		£	s.	d.
Oct. 31	To Halifax Corporation Mortgage Bond ...	350	0	0
	,, Life Members' Subscriptions	18	18	0
		£368	18	0

1907.		£	s.	d.
Oct. 31	By Transfer to Revenue A/c	8	18	0
	,, Halifax Corporation Mortgage Bond ...	350	0	0
	,, Cash in Bank to Reserve A/c	10	0	0
		£368	18	0

Leeds, November 5th, 1907.

I hereby certify that I have duly audited the above accounts, and have examined the vouchers, and found them to be correct.

F. W. BRANSON, *Hon. Auditor.*

WM. SIMPSON,
Hon. Treasurer.

OFFICIAL LIST OF MEMBERS.

HONORARY MEMBERS.

1887 Bodington, N., Litt.D., Vice-Chancellor, The University, Leeds.

1887 Hughes, Prof. T. McK., M.A., F.R.S., F.G.S., Ravensworth, Brooklands Avenue, Cambridge.

1887 Judd, Prof. Jno. W., C.B., LL.D., F.R.S., F.G.S., 22, Cumberland Road, Kew, Surrey.

1887 Woodward, Henry, LL.D., F.R.S., 13, Arundel Gardens, Notting Hill, London, W.

1907 Woodward, Arthur Smith, L.L.D., F.R.S., F.L.S.

1898 Whitaker, William, B.A., F.R.S., F.G.S., Freda, Campden Road, Croydon.

ORDINARY MEMBERS.

* Life Members who have compounded for the annual subscriptions.

Elected.

1883*Abbott, R. T. G., F.S.I., Whitley House, Malton.

1907*Ackroyd, Hy. Ed. P., Dean House, North Brierley, Bradford.

1903 Ackroyd, Wm., M.E., F.I.I., Nan Tan, Wortley, Leeds.

1901*Anderson, Tempest, M.D., F.G.S., 17, Stonegate, York.

1899 Appleyard, J. H. R., B.Sc., 5, Willow Lane East, Huddersfield.

1900 Ashley, Theodore, Stoneleigh, Newbold, Ashby-de-la-Zouch.

1900 Ashworth, John Hoyle, Wood Rhydding, Ilkley.

1875 Atkinson, J. T., F.G.S., Hayesthorpe, Holgate Hill, York.

1879*Bartholomew, C. W., Blakesley Hall, near Towcaster.

1899 Bean, J. A., F.G.S., Moot Hall, Newcastle-on-Tyne.

1878 Bedford, J. E., F.G.S., Arncliffe, Shire Oak Road, Headingley, Leeds.

1903 Beverley, Robert B., Heath House, Wakefield.

1895 Bingley, Godfrey, Thorniehurst, Shaw Lane, Headingley, Leeds.

1906 Bone, Prof. W. A., F.R.S., The University, Leeds.

1905 Booth, John, 15, School Hill, Windhill, Shipley.

1907 Booth, Peter, 65, Richmond Avenue, Leeds.

1899 Bould, Chas. H., 4, Welton Place, Hyde Park, Leeds.

1876*Bowman, F. H., D.Sc., F.R.A.S., F.C.S., Spinningfield, Deansgate, Manchester.

1907 Bradshaw, Chas., F.G.S., Public Museum, Weston Park, Sheffield.

1896 Bradley, F. L., Ingleside, Malvern Wells.

1894 Branson, F. W., F.I.C., F.C.S., 14, Commercial Street, Leeds.

1875*Brigg, John, M.P., F.G.S., Kildwick Hall, Keighley.

1905 Brodrick, Harold, M.A., 7, Aughton Road, Birkdale Lancs.

1877 Brooke, Sir Thos., Bart, J.P., Armitage Bridge, Huddersfield.

1907 Brooke-Fox, F. G., F.G.S., Ringmore Vean, Kingsbridge, S. Devon.

1904 Brown, Rev. G. H., Croft House, Otley.

1907 Brown, T. E., Salterforth, via Colne, Lancs.

1887 Brownridge, C., M.Inst.C.E., F.G.S., 26, North Road, Devonshire Park, Birkenhead.

1882*Buckley, George, Waterhouse Street, Halifax.

1896 Burrell, B.A., F.I.C., F.C.S., 8, Springfield Mount, Leeds.

1904 Burton, Jos. J., Rosecroft, Nunthorpe, R.S.O.

1907 Burton, W. J. P., F.G.S., Friarage Avenue, Northallerton.

1903 Carlton, John, 48, Albany Street, Hull.

1905 Carpenter, F. G., Savile House, Stanley Road, Wakefield.

1900 Carr, Professor J. W., M.A., F.L.S., F.G.S., University College, Nottingham.

1892*Carter, Rev. W. Lower, M.A., F.G.S., Belfield, Oxton, Birkenhead.

1876*Cash, W., F.G.S., 35, Commercial Street, Halifax.

1891*Chambers, J. C., Edgerton Road, West Park, Leeds.

1875*Charlesworth, J. B., J.P., Hurts Hall, Saxmundham.

1906 Cheetham, C. A., Glenmoor, Upper Armley, Leeds.

1892*Childe, Hy. Slade, F.G.S., Mining Engineer, Wakefield.

1903 Chippendale, Amos, Sindale House, Harrogate.

1877*Clark, J. E., B.A., B.Sc., Asgarth, Riddlesdown Road. Purley, Surrey.

1875 Cole, Rev. E. Maule, M.A., F.G.S., Wetwang Vicarage, near York.

1889 Crewe, Earl of, Crewe Hall, Crewe.
1897 Crofts, William Hastings, 16, Ash Grove, Newland, Hull.
1899 Crossley, Abraham, 62, Wellington Road, Todmorden.
1894*Crowther, Henry, F.R.M.S., Philosophical Hall, Leeds.
1904 Culpin, H., 7, St. Mary's Road, Doncaster.
1899 Dalzell, A. E., 3, Wesley Court, Crossley Street, Halifax.
1879*Dakyns, J. R., M.A., Snowdon View, Gwynant, Beddgelert, Carnarvon.
1883 Dalton, Thos., South Parade, Leeds.
1894*Davis, James Percy A., Chevinedge, Halifax.
1903 Davis, A. H., M.A., Walton Pines, Clevedon, Somerset.
1900*Dickons, J. Norton, 22, Park Drive, Heaton, Bradford.
1902 Dixon, Ed. Wilson, M.Inst.C.E., 14, Albert St., Harrogate.
1886*Dobinson, Launcelot, Park View, Stanley, near Wakefield.
1887*Duncan, Sir S. W., Bart., Horsforth Hall, Leeds.
1896 Dwerryhouse, Arthur R., D.Sc., F.G.S., Glyn Garth, Weetwood, Leeds.
1879 Eddy, J. Ray, F.G.S., Carleton Grange, Skipton.
1904 Edwards, E. J., M.Sc., University College of South Wales and Monmouthshire, Cardiff.
1905 Elliott, Sir Charles, K.C.M.G., C.B., Vice-Chancellor, The University, Sheffield.
1894 Embleton, Henry C., Central Bank Chambers, Leeds.
1895*Farrah, John, F.R.Met.S., Jefferies Coate, York Road, Harrogate.
1887*Fennell, Chas. W., F.G.S., 82, Westgate, Wakefield.
1902 Fitzwilliam, Earl, Wentworth Woodhouse, near Rotherham.
1883*Fleming, Francis, Elm Grove, Halifax.
1893 Forsyth, David, D.Sc., M.A., 101, Caledonian Road, Leeds.
1894 Fox, C. E., P.A.S.I., 22, George Street, Halifax.
1906 Frost, Rev. G. Percy H., M.A., Tanfield Rectory, Bedale.
1891*Furness, Sir Christopher, M.P., Brantford, West Hartlepool.
1890 Garforth, W. E., C.E., F.G.S., Snydale Hall, Pontefract.
1907 Gibson, Joseph, F.R.M.S., Elmfield, Psalter Lane, Sheffield.
1907 Gilligan, Albert, B.Sc., The University, Leeds.
1905 Glauert, Ludwig, Jun., F.G.S., 21, Kenwood Park Road, Sheffield.

1881 Gleadow, F., 38, Ladbroke Grove, London, W.

1905 Grace, George, B.Sc., Technical School, Barrow-in-Furness.

1907 Gott, Chas. Hy., F.G.S., M.I.C.E., F.R.M.S., 8, Charles Street, Bradford.

1904 Gregory, E. E., Thornfield Cottage, Bingley.

1905 Green, H. G. H., Claremont, Bradford Road, Wakefield.

1898 Haldane, George W., M.E., Old Corn Exchange, Wakefield.

1843 Halifax, Viscount, Hickleton Hall, Doncaster.

1905 Halton, George, 13, Regent Park Terrace, Headingley, Leeds.

1906*Hargreaves, Walter, Rothwell Haigh, Leeds.

1895 Harker, Alfred, M.A., F.R.S., F.G.S., St. John's College, Cambridge.

1905 Hartley, R. T., M.I.Mech.E., Borough Waterworks Engineer, Halifax.

1887 Hastings, Geoffrey, 15, Oak Lane, Bradford.

1896 Hawkesworth, Edwin, Sunnyside, Crossgates, near Leeds.

1907 Highfield, E. G., B.Sc., 18, Hall Garth, Pickering.

1905 Hill, Charles Alexander, M.B., D.Ph., 13, Rodney Street, Liverpool.

1900*Hind, Wheelton, M.D., F.G.S., Roxeth Hse., Stoke-on-Trent.

1905 Hodges, Isaac, Whitwood, Normanton.

1881 Horne, Wm., F.G.S., Leyburn.

1890*Howarth, J. H., J.P., F.G.S., Somerley, Rawson Avenue, Halifax.

1882*Hudleston, W. H., F.R.S., F.G.S., 8, Stanhope Gardens, South Kensington, S.W.

1907 Hummel, Ernest, B.Sc., c/o The University, Leeds.

1902*Ibbotson, John, Fitzalan Square, Sheffield.

1907 Ibbotson, William, 144, Burngreave Road, Sheffield.

1895*Imbery, John, Norfolk Mount, King Cross Street, Halifax.

1903*Ingham, Edward T., J.P., Blake Hall, Mirfield.

1904 Johns, Cosmo, F.G.S., M.I.Mech.E., Burngrove, Pitsmoor Road, Sheffield.

1901 Johnson, Rev. W., B.A., B.Sc., Archbishop Holgate's School, York.

1905 Jones, Rev. E., Embsay.

1887*Jones, J. E., Solicitor, Halifax.

1897 Jowett, Albert, M.Sc., The Technical School, Bury.

1905 Jordan, Albert, St. John's Road, Balby, Doncaster.

1892 Kendall, Professor Percy F., M.Sc., F.G.S., 5, Woodland Terrace, Chapel-Allerton, Leeds.

1905 Kenworthy, Joseph, Stretton Villa, Deepcar, near Sheffield.

1902 Kidston, Robert, F.R.S., F.R.S.E., F.G.S., 12, Clarendon Place, Stirling.

1907 Kitchin, Matthew, c/o H. C. Embleton, Central Bank Chambers, Leeds.

1897*Kitson, R. H., F.G.S., Elmet Hall, Leeds.

1877*Lamplugh, G. W., F.R.S., F.G.S., 13, Beaconsfield Road, St. Albans.

1894 Law, Arthur W., Greetland, Halifax.

1903*Lawrence, J. P., A.M.I.C.E., Scriven, near Knaresborough.

1907 Lindley, W. E., Westfield, South Lane, Shortlands, Kent.

1906 Lofthouse, J. H., Lyell House, Dragon Parade, Harrogate.

1901 Lomas, Joseph, F.G.S., 13, Moss Grove, Birkenhead.

1905 Longbottom, J. Leonard, Dingleside, Gledholt, Huddersfield.

1906 Lund, Percy, 57, Southfield Square, Manningham, Bradford.

1877*Lupton, Arnold, M.P., F.G.S., M.Inst.C.E. 7, Victoria Street, Westminster.

1905 Macturk, G. W. B., 15, Bowlalley Lane, Hull.

1905 Margerison, Samuel, Grey Gables, Calverley, near Leeds.

1905 Massie, Frank, A.M.I.C.E., F.S.I., Tetley House, Wakefield.

1905 Milton, J. H., F.G.S., Harrison House, Crosby, Liverpool.

1907 Mitchelson, James M., J.P., The Hall, Pickering.

1896 Moreton, Henry James, Ship Hotel, Royston.

1879*Morrison, Walter, J.P., Malham Tarn, Settle.

1878 Mortimer, J. R., Driffield.

1906 Mott, C. F., M.A., Giggleswick.

1894*Muff, H. Brantwood, B.A., F.G.S., 33, George Square, Edinburgh.

1895 Muller, Harry, 12, West Chislehurst Park, Eltham, Kent.

1903 Naylor, E., Heather Bank, Hazelhurst Road, Bradford.
1902 Nettleton, Stanley, Roundwood, Ossett.
1898 Nevin, John, J.P., F.G.S., Littlemoor, Mirfield.
1889*Nicholson, M., J.P., Middleton Hall, near Leeds.
1899*Ormerod, William, Kershaw House, Luddendenfoot.
1875*Parke, G. H., F.G.S., F.L.S., St. John's Villas, Wakefield.
1892*Pawson, A. H., F.L.S., F.G.S., Howe Combe, Watlington, Oxon.
1906 Phillips, John H., Tregolan, Bradford Place, Penarth, Glam.
1905 Pickles, Herbert, B.A., 5, Brudenell Mount, Hyde Park, Leeds.
1904*Pollard, John, F.G.S., 56, Westgate, Wakefield.
1897 Pratt, Rev. Chas. T., M.A., Cawthorne Vicarage, near Barnsley.
1905 Punch, J. W. R., Hastoe House, Southfield Road, Middlesbrough.
1859*Ramsden, Sir J. W., Bart., Byram Hall, near Pontefract.
1904 Rastall, R. H., M.A., F.G.S., Christ's College, Cambridge.
1907 Ratcliffe, H. B., Exchange Buildings, Bank Street, Bradford.
1864*Rhodes, John, Bolton Royd, Bradford.
1856*Ripon, The Marquis of, K.G., F.R.S., &c., Studley Royal, Ripon.
1907*Robinson, John Gorges, B.A., J.P., Cragdale, Settle.
1898 Robinson, William, Greenbank, Sedbergh, R.S.O.
1906 Robinson, W. J., 54, Cardigan Lane, Leeds.
1901 Roebuck, W. Denison, F.L.S., 259, Hyde Park Road, Leeds.
1907 Roome, G. W. B.Sc., F.G.S., 214, Psalter Lane, Sheffield.
1903*Rowe, Arthur W., M.S., M.B., F.G.S., 1, Cecil Street, Margate.
1902 Rowland, Lewis G., 3, St. Hilda's Terrace, Whitby.
1896*Rowley, Walter, F.G.S., F.S.A., 20, Park Row, Leeds.
1882 Scarborough Philosophical Society, The Museum, Scarborough.
1905 Sewell, J. T., Chubb Hill Road, Whitby.
1897*Sheppard, Thomas, F.G.S., 392, Holderness Road, Hull.
1906 Sibson, Ernest E. O., 6, Lax Terrace, Norton, Stockton on-Tees.

1892*Simpson, W., F.G.S., Catteral Hall, Settle.

1904*Simpson, J. T., J.P., Brackenholm, Rutland Road, Harrogate.

1887 Slater, M. B., F.L.S., 84, Newbiggin, Malton.

1879 Slingsby, W. C., Carelton, near Skipton.

1876*Smith, F., Dunham Lawn, Bowden, Cheshire.

1851 Sorby, H. C., D.C.L., F.R.S., F.G.S., Broomfield, Sheffield.

1875 Stanhope, Sir Walter Spencer, K.C.B., Cannon Hall, Barnsley.

1881*Stansfeld, Alfred W., Dacre House, Rock Ferry, Cheshire.

1900*Stansfield, W. G., Wilton House, The Grove, Ilkley.

1890 Stather, John W., F.G.S., Brookside, Newland Park, Hull.

1894 Stears, John, Westholme, Hessle, near Hull.

1898*Stewart, William, Brooklyn, Crigglestone, Wakefield.

1885*Stockdale, T., Spring Lea, Leeds.

1878 Strangways, C. Fox, F.G.S., Kylemore, Hollycroft Avenue, Hampstead, London, N.W.

1879*Strickland, Sir Charles W., Bart., Hildenly, Malton.

1902 Stringer, G. E., Junior, Slingsby Hall, York.

1894 Sutcliffe, J. W., The Hollies, Greenroyd, Halifax.

1888 Sykes, Sir Tatton, Bart., Sledmere House, near York.

1902*Sykes, Alfred, Woodville, Thongs Bridge, Huddersfield.

1897*Teal, Joseph, Banksfield House, Yeadon, near Leeds.

1894 Tetley, Ed. H., B.A., 18, Moorland Road, Leeds.

1880 Tetley, C. F., M.A., Spring Road, Headingley, Leeds.

1886 Thompson, R., Dringcote, The Mount, York.

1902 Thompson, Professor G. R., B.Sc., The University, Leeds.

1905 Thompson, Hubert, B.Sc., The College, Saltersford Hall, Holmes Chapel, Cheshire.

1875*Tiddeman, R. H., M.A., F.G.S., 175, Banbury Road, Oxford.

1907 Tiffany, F., B.Sc., Engineer's Office, Midland Railway, Derby.

1904 Townend, George F., Pleasant View, Earby, Colne, Lancs.

1899*Turton, Robert B., Kildale Hall, Grosmont, Yorks, R.S.O.

1899 Uttley, William H., 3, Hollins View, Hill Top, Sowerby Bridge.

1905 Veitch, W. Y., L.R.C.P., L.R.C.S., F.G.S., 6, Southfield Villas, Middlesbrough.

1905*Vickers, T. E., C.B., M.Inst.C.E., M.I.Mech.E., River Don Works, Sheffield.

1905 Wadsworth, Rev. H., F.R.M.S., The Grange, Wadsley Bridge, Sheffield.

1907 Wager, Morton E., B.Sc.(Lond.), Cragg Road, Mytholmroyd, Yorks.

1905 Walker P., Old Corn Exchange, Wakefield.

1906 Walker, William, H.M. Inspector of Mines, Doncaster.

1884*Walmsley, A. T., M.Inst.C.E., F.S.I., F.K.C., Engineer to the Dover Harbour Board, 9, Victoria Street, London, S.W.

1894 Walton, F. Fielder, F.G.S., L.R.C.P., 19, Charlotte Street, Hull.

1875*Ward, J. Whiteley, J.P., F.R.M.S., South Royd, Halifax.

1898 Wellburn, Edgar D., L.R.C.P.E., F.G.S., Beech House, Sowerby Bridge.

1906 Wells, George John, 14, Bannerdale Road, Sheffield.

1900 Wharncliffe, Earl of, Wortley Hall, Sheffield.

1881*Whiteley, Fredk., Corn Market, Halifax.

1889 Wilkinson, J. J., Burnside, Skipton.

1906 Willey, Edward, B.Sc., c/o New Mysore Manganese Co. Ltd., Shimoga, Mysore, India.

1894 Williams, W. Clement, F.R.I.B.A., Corn Market, Halifax.

1905 Wilmore, Albert, B.Sc., F.G.S., Technical School, Colne, Lancashire.

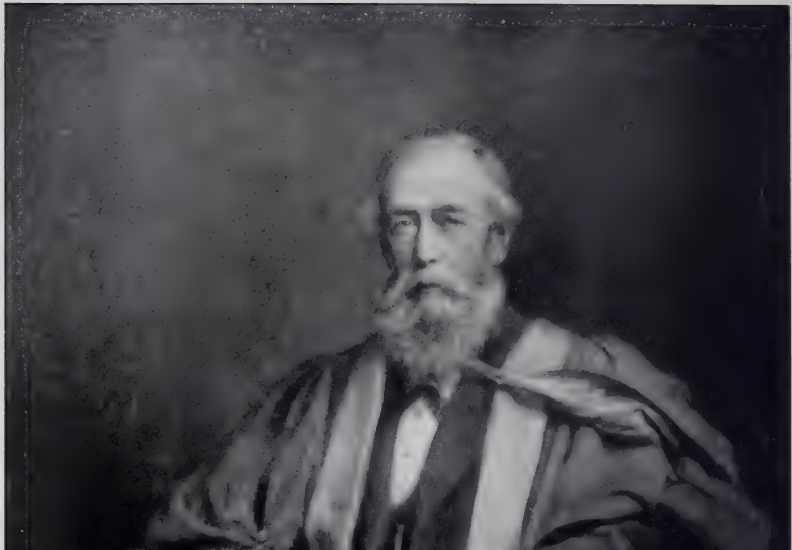
1890 Wilson, Colonel Edmund, Denison Hall, Leeds.

1894 Wilson, J. E., F.G.S., Dunholm, Ilkley.

1897 Wilson, J. Mitchell, M.D., County Hall, Beverley.

1906 Wilson, J. R. R., M.Inst.C.E., H.M. Inspector of Mines, 182, Chapeltown Road, Leeds.

⁂ It is requested that any Member changing his residence will communicate at once with the Hon. Secretary.



H. C. Sorby

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXVI.

VOL. XVI.] [PART III.

PROCEEDINGS
OF THE
YORKSHIRE GEOLOGICAL SOCIETY.

EDITED BY ARTHUR R. DWERRYHOUSE, D.Sc., F.G.S.

1908.

In Memoriam.

HENRY CLIFTON SORBY.

1826–1908.

During the past year the Society has had to deplore the loss of one of its oldest members and Yorkshire perhaps the most brilliant original genius to which the county has given birth.

The son of a well-to-do tool manufacturer and colliery proprietor, Sorby received a liberal education, first in a private school and at the Grammar School of his native town, Sheffield ; while later, by a most fortunate choice, he was placed under the tuition of the Rev. Walter Mitchell, a man whose wide attainments in mathematics, physical science, and anatomy fitted him in eminent degree to give such an insight into different aspects of natural science as would arouse and stimulate Sorby's inherent tastes and aptitudes.

The sympathetic biographical notices by Mr. Thomas Sheppard* and Professor J. W. Judd† render it unnecessary to review in detail Sorby's works. A nearly complete bibliography, in the compilation of which he himself assisted, is published in the "Naturalist," and it will be seen how versatile were his talents and how wide was the range of his interests. There is scarcely any department of science but owes to Sorby's genius some brilliant and fructifying idea or some beautiful and ingenious method of research. To chemistry he contributed his first paper and to geology his last, but physics, botany, zoology, sanitary science, forensic medicine, meteorology, metallurgy, mineralogy all received important contributions.

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* "Naturalist," 1906, pp. 137-144, 194-197, and 225-230.

† Geol. Mag., May, 1908. Mineralogical Mag., Nov., 1908. Journ. R. Micr. Soc., 1908, pp. 431-5.

To geologists the name of Sorby will always stand associated with the foundation of the science of microscopic petrology.

Though the investigation of the optical properties of minerals by means of thin sections of crystals had been carried on long before his time, it was by Sorby that similar methods were applied to thin sections of rocks. The art of grinding sections of hard substances such as bones, teeth, fossil corals, and the like had long been practised, and having learned from the late Professor W. C. Williamson, who was an adept, the methods, Sorby applied them to the preparation of rock sections; but, for the successful study of his slices new optical appliances were required, and these he designed and adapted to the microscope. Sorby's first rock section, a photo-micrograph of which is appended hereto (Plate XXVII., Fig. 1, and Plate XXVIII., Fig. 1.), is little inferior to the work of the English professional section cutters of to-day.

The first product of his new method was a paper contributed to the Geological Society of London in 1850 on the Microscopical Structure of the Calcareous Grit of the Castle Rock at Scarborough, and it is interesting to us to note that in the Proceedings of the West Yorkshire Geological Society for the following year* an amplification of this paper was issued with the first illustrations of minute rock structures ever published. Sorby followed this up with detailed studies of sedimentary and other rocks and investigations of the mineralogical constitution of calcareous organic structures, a very important subject to which

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* Vol. III., pp. 197-206 and Plate IV.

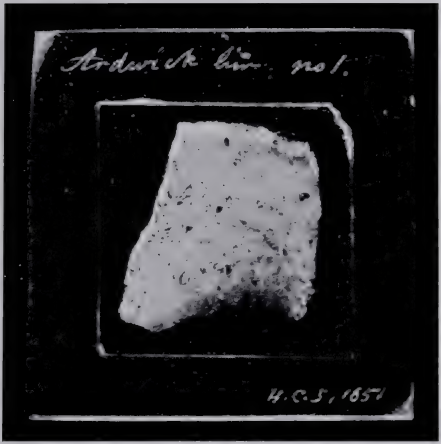
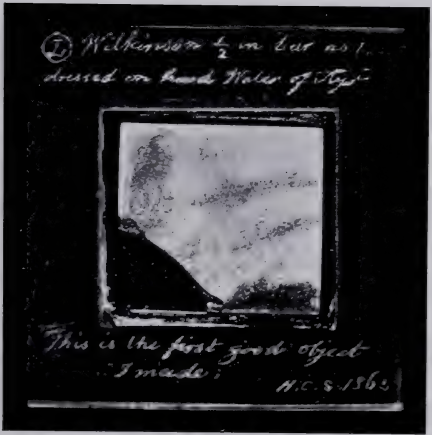


Fig. 1.


① Wilkinson ½ in bar as 1,
dressed on hand Water of Ayr
This is the first good object
I made;
H.C.S. 1862

Photographed by A. R. Dwerryhouse.

Fig. 2.

PHOTOGRAPHS OF SORBY SLIDES.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXVII.

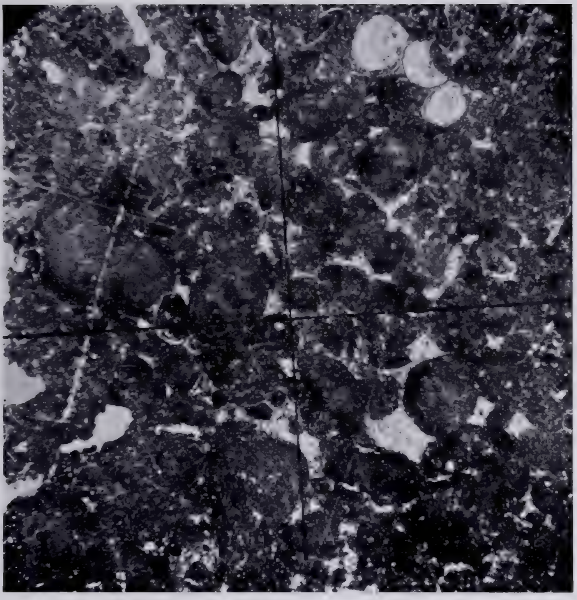
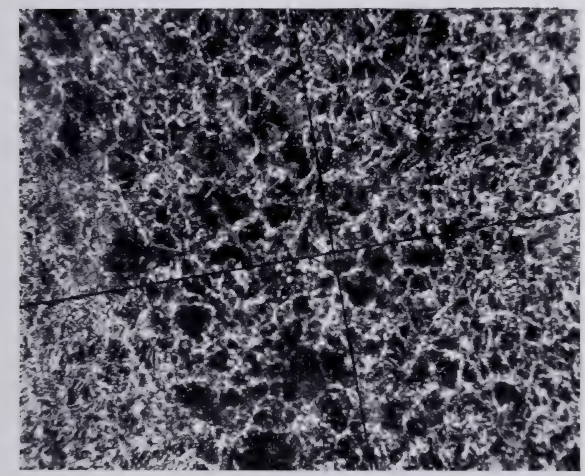


Fig. 1.



Photographed by A. R. Dwerryhouse.

Fig. 2.

PHOTO-MICROGRAPHS OF SORBY SLIDES.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXVIII.

little has been added since, whereas the study of microscopic petrology has attained to transcendent importance and a literature of vast extent.

It is difficult to select from Sorby's many other geological researches those most worthy of mention in this brief notice, but his discovery of the true cause of slaty cleavage is one that cannot be omitted. Prior to its publication various chemical, electrical, and other agents had been invoked, but Sorby's explanation that lateral pressure, by causing the rotation of inequiaxed particles of the rock materials, had imparted a tendency to cleave in planes perpendicular to the pressure, agreed so well with observation in the field and with the minute structure of slate, that nothing has since been seriously urged against it, though greater importance may now be assigned to "shear" than formerly.

The last paper emanating from Sorby's fertile mind appeared in the Quarterly Journal of the Geological Society after his death. It deals with the phenomena of the deposition of sands and clays, and is based upon observations and experiments extending over a period of nearly 60 years. Many of the experiments, of a delicate and refined character, were conducted during the last few months of his life, while the author was lying stricken with partial paralysis. This paper displays all those qualities of the ingenious experimenter and acute reasoner that we have been accustomed through so many years to associate with our ideas of Sorby and his work, and if in some instances the final demonstration seems not quite complete, we may well attribute the defect to the peculiar circumstances under which the paper was written, and the eagerness of the author to finish what he declared to the present writer to be the crowning work of his life.

Mention must be made of one other achievement of Sorby's, the discovery by means of polished and etched surfaces of metals of the true structure of iron and steel. The section (Plate XXVII., Fig. 2, and Plate XXVIII., Fig. 2) is inscribed with a diamond (Sorby's general custom with his microscopic preparations): "This is the first good object I made." These words are sufficient to invest the illustration with the utmost interest, not only to metallurgists, to whom his work has been of inestimable value, but also to geologists and others, who see in the remarkable "Sorbitic" structures disclosed close and highly suggestive analogies with the structure both of terrestrial igneous rocks and still more with the structure of meteorites made known to us by Sorby's own researches.

Sorby lived a life of strenuous scientific work, harassed fortunately by no cares, and upheld constantly by an eager and sanguine enthusiasm. To the younger generation of geologists his example is full of inspiration, and no more profitable exercise could be commended than a careful perusal of his papers.

PERCY F. KENDALL.

[We have to thank the authorities of the University of Sheffield for kindly lending the slides from which Plates XXVII. and XXVIII. have been photographed.—ED.]

In Memoriam.

JOSEPH LOMAS.

It is a sorrowful task to have to record the loss of a dear friend and excellent geologist, cut off in the prime of health and vigour by a railway accident at El Uchain, in Algeria, on the 17th December, 1908.

Mr. Lomas came of a family long-established in Derbyshire in the neighbourhood of Bugsworth. His school career was marked by a long series of successes, resulting in his entering the Royal School of Mines and Normal School of Science as a Teacher in Training, and it was here that, as fellow-students under Huxley and Judd, a lifelong and intimate friendship was formed between him and the present writer. They passed through the courses together, and their names were never separated in the examination lists.

Upon the completion of his career at the schools, Mr. Lomas took up the position of Lecturer in Science under the Liverpool School Board, and subsequently assumed the full control of their organisation for science teaching. Besides this, he gave courses of lectures at University College, which were continued down to the time of his death. He entered fully into the scientific life of the city, and his fresh enthusiasm and high ability as a teacher have had a most important influence in stimulating interest in geology throughout the district. The Liverpool Geological Society elected him to the presidential chair in 1896, and he was selected as the geologist best qualified to again occupy that position in the year 1909, when the Society would celebrate its jubilee.

The British Association, of which Mr. Lomas had been a very active member for several years, appointed him the chief secretary of the Geological Section, and it is safe to say that it will not be easy to find so energetic, able, and generally popular a geologist to succeed him.

Mr. Lomas's original work has been of a very varied character, including work upon the recent marine polyzoa, as well as purely geological researches, and at the time of his death he was travelling in Algeria in the prosecution of systematic investigations into the geological phenomena of deserts, especially in relation to the Triassic rocks which had been selected by Mr. Lomas as the main object of his scientific studies. The researches upon which he was engaged were being prosecuted with the aid of a grant from the British Association, and it adds an additional pang to the sorrow we feel that his career should have been thus brought to an untimely close just when the prospects of distinguished achievement seemed brightest and most hopeful.

P. F. KENDALL.

INGLEBOROUGH.

PART VI. THE CARBONIFEROUS ROCKS.

BY T. McKENNY HUGHES, M.A., F.R.S., WOODWARDIAN PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF CAMBRIDGE.

(*Manuscript received November*, 1908.)

INTRODUCTORY.

" Professor Sedgwick's examinations of the North of England have the same date as my own," said Phillips. " We met for a few moments near the High Force in 1822; after ten years of independent research we compared results at Cambridge, and I found with great satisfaction that my conclusions, drawn chiefly from examining the interior of the district, were consonant to those of my distinguished friend derived chiefly from the western border."*

Sedgwick, a representative of the ancient race in which the blood of the stalwart Scandinavian was mingled with that of the Romanised Briton, and Phillips, of the stout hearted Silurian stock of South Wales, worked, the one in the land of his birth and the other in the land of his adoption, and so bravely did they carry their researches into the wild moorlands, and so keen their eye and so sound their judgment, that with all the help of modern appliances in an opened-up country, we can rarely improve upon their field work, except by filling in details or altering a bracket; but they warned us that their "lines of division contain much that is arbitrary, and more that is merely of local application."

I shall endeavour, as far as possible, not to introduce into this sketch any shibboleths that will make it difficult to refer to the descriptions which they have given, though a large proportion of the fossils have different names from those by which they were known when I began to work on Ingleborough. Many a student who could do good work and help on the interpretation of the phenomena presented to him at every turn in the glorious country to which it has happily fallen to our lot to have our attention called, is thwarted at every step and, perhaps, altogether deterred from seriously pursuing the work by the introduction of theory into nomenclature and the consequent perpetual change of the common names by which we try to call up the idea of the thing about which we are talking. I write for students. There is many a one who would of all things like most to have offered to him some subject for original research. To such we may say that a walk in any district or round any museum must suggest many points which he does not clearly comprehend. To work out such is for him original research. But that is not what he wants, for he often finds, when he has examined and collected, and is beginning to understand, that the work has been done before. He seeks, and a legitimate ambition it is, to do something new—to add something to the sum of knowledge. What advice shall we give to such a one, whose tastes lead him by flood and fell to study the building up of the rocks and the story of the changing life that in successive ages dwelt upon the earth ? Go and see and record what you see.

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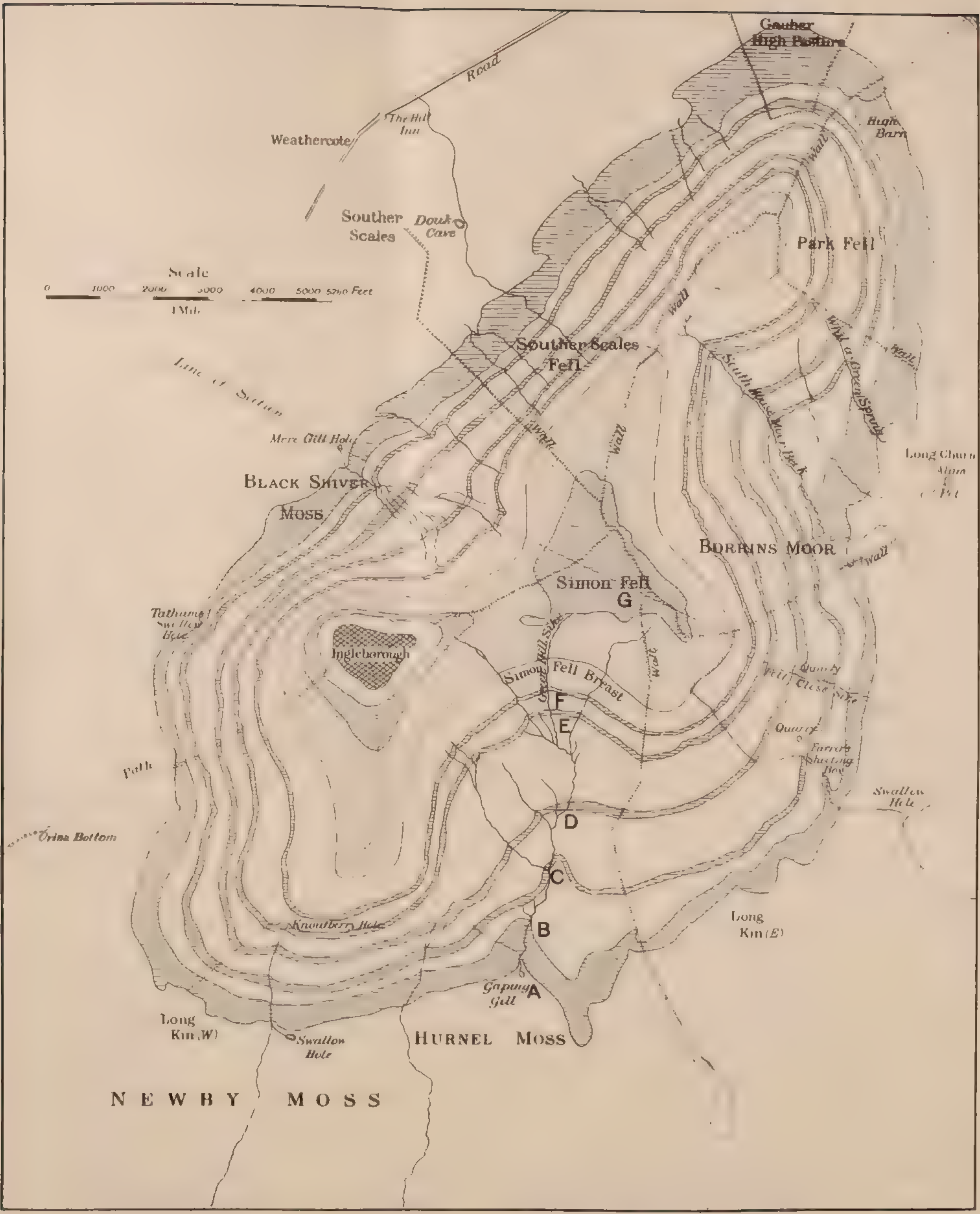
* Phillips' Geology of Yorkshire. Introduction, p. 18.

The first essential for geological research is mapping. If it has not been done for you, you must put down on a plan the geographical " appearances " of the rocks from which you get the geological sequence which you indicate on sections.

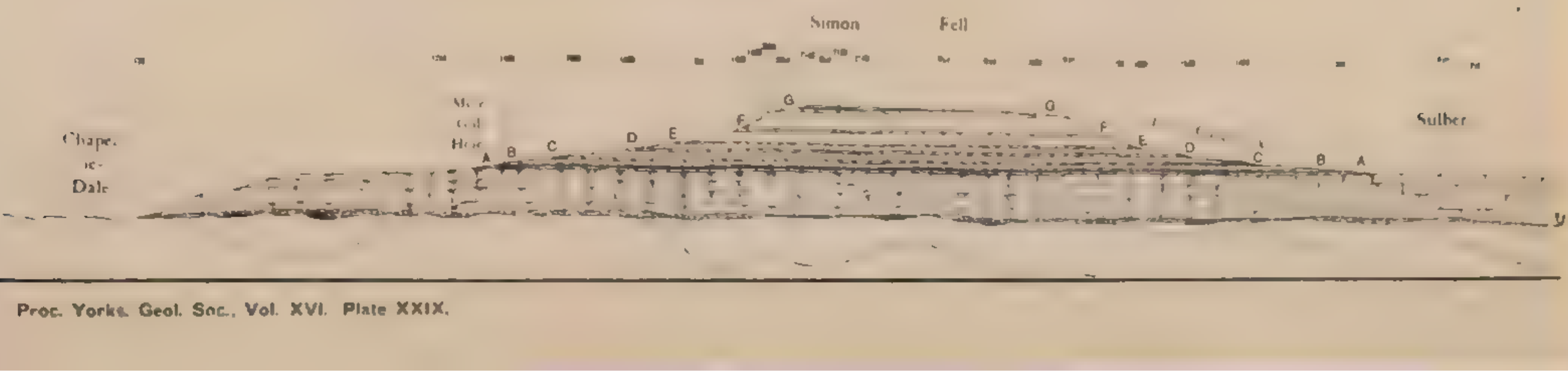
Then you may examine in detail each horizon, so that you can, by the lithological character and the fossils, identify each bed even when the exposures are separated by intervening masses of drift and the rock is seen only here and there.

You must remember that characteristic fossils are not only those which are *peculiar* to a bed, but those also which are so numerous at a certain horizon or in a certain spot as to make the rock easily recognisable by them. The zones of the Carboniferous rocks of Ingleborough are not yet worked out, and this work will not be quickly done. It requires much knowledge and much study of palæontological literature. But valuable contributions are being offered from time to time, and every step makes the next easier.

Supposing our student asks for something more definite and limited in scope, let him take certain forms of life, such as



Section W.N.W. & E.S.E. from Chapel-le-Dale across Simon Fell to Sulber.



the corals, or the brachiopods, or even certain genera only, such as *Cyathophyllum* or *Producta*, and note their range, change, and sometimes recurrence, in the great ascending section. This would be a most valuable piece of work. It would be to apply to one clear section the methods sketched out by that brilliant naturalist, Edward Forbes.* He points out that :—(1) Species of opposite hemispheres placed under similar conditions are representative and not identical ; (2) species occupying similar conditions in geological formations far apart, and which conditions are not met with in the intermediate formations, are representative and not identical ; (3) whenever a given assemblage of conditions, to which, and to which only, certain species are adapted, are continuous—whether geographically or geologically —identical species range throughout.

But he also explains, further on, that when forms have been banished from any area owing to the temporary occurrence of unfavourable conditions they may have lived on close by, and have, when favourable conditions recurred, migrated back into the area from which they had been driven. Perhaps, if it was a question of depth that influenced them, much sedimentation may have taken place in the interval—and we shall recognise identical species separated by a great thickness of deposit. I believe that proofs of this are to be found on Ingleborough.

That question of representative forms opens out a very wide field of inquiry.

The carnivora which in one area keep down the redundancy of ruminants may belong to totally different genera from those which discharge the same function in another, and so also in time the fossil carnivores of any district may be quite different from those which live there now. These are representative in one sense. Among the lower forms of life also, at one time or in one area, corals or brachiopods or lamellibranchs may predominate and feed on lower organisms. But all of these, though representative in the functions they discharge, are not directly derived one from the other, and do not point to modification accompanying if not caused by environment. Another interesting line of research is where we find in one area a certain well-marked species or variety, and in another area, at the same time, similar or closely allied forms suggesting a contemporary modification for which we can sometimes find a cause in changes of sediment, of depth of water, or other conditions—though accident often mixes up the modified forms, so that, although their area of development and normal habitat may have originally been different, they are now thrown together.

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* On the connection between the Distribution of the existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their area, &c., by Edward Forbes, Mem. Geol. Survey, Vol. 1, p. 336.

What contribution can our student make towards the working out of these interesting questions ? Let him select any one horizon in which he sees a fair abundance of certain allied forms and collect all he can, being careful to look out for intermediate varieties ; let him arrange them to illustrate the gradual passage from one variety to another, and he will probably be rewarded by finding that what have been regarded as distinct varieties and species can, by the interpellation of intermediate forms, be run into one variable group. I have in the Sedgwick Museum many series of ammonites, gasteropods, and brachiopods, arranged in continuous sequence, and passing, without any sensible break, through four or five or more species. We shall see as we go on how much this is wanted for Ingleborough. When our student has worked this out, then, and not till then, will he be in a position to appreciate the modification of species as time went on. On Ingleborough we have an unbroken sequence of some 1,500 or 1,600 feet of Carboniferous rocks within an area of very small extent, so that we can study the modification of species in time without taking account of their geographical distance apart.

To make this sort of work possible the first essential is a map which must be based upon those differences of sedimentation, lithological character, and structure to which the obvious features are due. For these stratigraphical features are easily recognised, and do not get altered continually with the progress of investigation. New quarries, keener eyes, more hammers turn out fossils where they had not been found before, and our ideas as to the range of certain forms have to be modified from time to time, but a band of limestone, for instance, carefully mapped, remains there always like a bench mark with which you must make your levels always agree.

Sections may be drawn from such a map when the contours are given and generalisations as to the persistence or variation of the deposits can hardly be studied without it.

As a contribution in aid of such general or special studies I offer first a map on which the outcrops of the principal limestones are shown. I have also in some cases indicated the probable boundaries of other formations which are nowhere clearly seen on Ingleborough, when their existence is suggested by surface features or the course of underground waters. I have drawn a few sections in which the superposition of those beds is more clearly shown in detail, and have pointed out where peculiarities of structure may be observed, and where fossils have been obtained at various important horizons.

THE GREAT SCAR OR MOUNTAIN LIMESTONE.

In the preceding part of this monograph I described the basement bed of the Carboniferous, emphasising what I had pointed out before (Vol. XIV., p. 134), that we have here to deal with one of the greatest breaks in the whole geological series. I pointed out the manner in which the pre-Carboniferous surface had been planed off, though not everywhere so deeply as to have swept away all traces of ancient valleys or of the deposits which had been washed into them. Remembering that the Carboniferous system here rests on a Sea Plain or Base Level of Erosion, we turn with great interest to an examination of the character of the sediment that was first laid down upon it. Sometimes it is a limestone which rests on the Bala and Silurian rocks with practically no conglomerate at the base, as in the Keld Cave in Chapel-le-Dale; but generally the lower beds are made up of fragments of the underlying rocks, and when these are derived from the Green Slate Series, or Silurian, they consist of angular chips. Higher up in the Carboniferous rocks these fragments are no longer seen, but bands and lines and scattered pebbles of quartz occur at various levels throughout the lowest beds of the Mountain Limestone—in Chapel-le-Dale generally up to 20 feet or so from the base, under Norber

Brow through a much greater thickness. At first the material did not appear to be much worn by transport, but later on, for some reason or other, the only fragments that reached this spot were far travelled pieces of quartz from which all trace of softer sediment had been removed, and which had themselves been rolled into small pebbles.

I drew special attention to the well-established fact that certain parts of the pre-Carboniferous floor must have gone down earlier than others, so that lower Carboniferous beds than any seen on Ingleborough were deposited in other areas before the submergence of the sea-plain, which here forms such a striking feature at the base of the Carboniferous conglomerate. When we come to examine the details we find that the Mountain Limestone thickens out enormously towards the Lune Valley, and unless repeated by undetected faults must, near Kirkby Lonsdale, be twice as thick as it is on Ingleborough, while on the north entirely different deposits occur, wedged in under the equivalents of the lowest beds of Ingleborough, and intercalated in the lower parts of the series, as shown by Prof. Harkness in his evidence before the Coal Commission.* Palæontologists who are at work on these beds are making out that the characteristic fossils of our lowest beds of Ingleborough correlate them with beds well up in the series, as developed in the west and north, while conglomerates, which represent the shingly shore of the encroaching Carboniferous sea, occur at the base everywhere, though they are of very different age.

Dr. Vaughan calls attention to the fact that the "appearances," to use Barrande's word, of one species do not always coincide with the "appearances" of another species; that is to say, that the changes of environment or other cause which brought about the disappearance of a particular brachiopod from a given area may not have acted in the same way or so quickly upon a group of corals. I remember Dr. Duncan urging at a meeting of the Geological Society the value of the sedentary coral for purposes of correlation of strata, and the correctness of this view has been well shown by Dr. Vaughan, who used them with such admirable results as zonal indices in the Bristol area. This section had been measured off by Dr. Lloyd Morgan and Mr. Stoddart each in his own way, but the corals and brachiopods are so well developed there, as indeed in most limestone areas of this age, that they are taken as the most convenient basis for the construction of the local vernier.*

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* See also Mem. Geol. Survey Expl. Sh., 97 S.W. old series, 102 S.W. old series, 30 new series.

I did not re-open the question of the glacial origin† of these beds, though its interest is revived by the discovery in so many parts of the world of conglomerates which appear to point to the local recurrence of glacial conditions throughout the whole of the geological series. To those who refer glacial phenomena chiefly to geographical changes this seems to be inevitable, but each case must be considered independently, and in that of our Yorkshire Basement Bed the evidence seems to be decidedly adverse to the view that the boulders owe their striæ to the action of ice.

The Structure of the Mountain Limestone.

Now we have to examine the new group in greater detail, and very curious are the phenomena presented. All of a sudden, above the basement bed, there succeeds a vast deposit of limestone. There has been nothing like it before in all the tens of thousands of feet of sediment which we see exposed below it all round. The Coniston Limestone, the only one we have in the district within sight, and the Gurrey Fach Limestone at a somewhat lower horizon in South Wales are thin, impure, earthy, impersistent beds. But in the Mountain Limestone of Ingleborough we find about 600 feet of almost pure carbonate of lime, with hardly enough clay and iron to furnish here and there a small layer of ferruginous earth at the bottom of a cave.

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* Cf. Cosmo Johns and Vaughan, Geol. Mag., Vol. III., 1906, p. 320. Garwood ib., Vol. IV., 1907, p. 70. See also the papers by Dr. Marr and Professor Garwood, e.g., Geol. Mag., 1907, p. 70.

† Cf. Phillips, Geology of Yorkshire, Vol. II., 1835, p. 14. Sharpe, F., Proc. Geol. Soc., Vol. III., 1842, p. 605. Godwin, Austen, Quart. Journ. Geol. Soc., Vol. XII., 1856, p. 53. Mem. Geol. Surv. Explanation Quarter Sheet, 98° S.E. Cummin, Rev. I. G., The Isle of Man, its History, &c., 1848, p. 89. Article on Geology in History and Topography of Cumberland and Westmorland, by W. Whellan, Pontefract, 1860, p. 28. Ramsay, Sir A., Quart. Journ. Geol. Soc., Vol. XI., 1855, p. 187. The Reader, Aug. 12th, 1865. Hughes, T. McKenny, Notes on the Geology of Parts of Yorkshire and Westmorland. Geol. Polyt. Soc. Yorks, Halifax, July, 1867. Mem. Geol. Surv. Explanation, 98° S.E., 1872, p. 15. Recurrence of Ice Ages, Proc. Camb. Phil. Soc., 4 parts, Vol. VIII., 1893, pp. 98, 219, 224, Vol. IX., 1896, p. 214.

That the Great Scar or Mountain Limestone of Ingleborough was laid down in clear water may be inferred from its purity, and that it was formed at some distance from the source of sediment seems probable from the rolled and rounded condition of the quartz pebbles in its lowest beds, and the absence of other foreign material, except quite at the base, where it was swept off the surface into hollows when the sea first crept over it. Further west the limestone thickens, and on the north gets split up by beds of sandstone, as mentioned above, while on the south it is sharply cut off by the great Craven faults.

Here we have a clearly defined area and a special development well worth careful study. We see that it was built up by the accumulation of the fragmental and comminuted remains of the hard calcareous parts ot organisms that swarmed over the sea bottom. It is more or less coarsely crystalline, and the appearance of crystalline structure in the rock is increased by the cleaved calcite of the encrinite stems and other bodies which go to make up the mass. There is distinct bedding throughout, but the beds differ much. Sometimes they are very thick, forming bluffs and scars ; while sometimes they are thin, irregularly lenticular, and lend themselves to more gently rounded outlines. When beds affected by these different qualities and structures are superimposed, many curious and beautiful features are produced. For instance, on Moughton and Norber, and less conspicuously in other outcrops of the Mountain Limestone round Ingleborough, we see massive beds undermined by the weathering out of softer strata below, and giving rise to caves and abris, just like those in which primæval man dwelt, or which, when walled up in front, furnished a shelter for the English soldiers who, in the Middle Ages, occupied the valleys of the Dordogne,* or those which in later times provided "cliff dwellings" for the Indians of Arizona,† and everywhere these natural features were enlarged, adapted, or even artificially imitated.

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* A. Laganne, Annales d'Agriculture de Dordogne. Lyell, Antiquity of Man, 1873, p. 134, and Fig. 12, p. 136.

† Proc. Camb. Ant. Soc., Vol. III., p. 23.

When we remember that this great mass of pure limestone is made up of the crushed fragments of shells and other calcareous parts of animals, it seems at first difficult to explain why we find so few whole specimens throughout great thicknesses of rock, whereas where such occur here and there they are remarkably well preserved. The analogy of the chalk, which is an earthy limestone similarly composed of comminuted calcareous parts of organisms, with well preserved specimens occurring here and there in bands or sporadically, teaches us that this character does not depend upon exceptional causes, but has to do with the ordinary mode of accumulation of great masses of limestone, without the intermixture of other sediment. These limestones were formed in *clear* water, but, as we are assured that the fauna does not in either case indicate *deep* water, we may infer that it was a sinking sea bottom teeming with life.

But why were the hard parts of the molluscs, the crustaceans, the echinoderms, all broken up into sand and mud ? If we turn to recent seas where corals abound, we find vast masses of coral which have been broken up by the lash of the waves and formed into great terraces and sloping banks of debris on which other corals build.*

In some parts of the world now, and in many successive geological formations in the past, we find remains of fish furnished with strong palatal teeth, with which they scrunch up the shells of the animals on which they feed. The fragments are rejected and strewn over the floor of the sea and, where further broken and rolled by the action of the waves, form a calcareous sand and mud. Some shells and echini secreted among the recesses of branching corals are saved, and an empty shell would not be touched by animals seeking food. Such accidents would account for much of what we see in the Carboniferous and Cretaceous Limestones.

The greater part, however, of recent limestones and probably of those of ancient times, is due to the same causes as produce the vast deposits of mud, sand, and shingle, of which the rocks are chiefly made up. Where corals grow there is not much rock exposed to denudation, and the waste of coral reefs and of the calcareous shells of creatures that live on it furnish the whole of the material which is heaped up on the sea margin and spread over the sea bottom, forming various textured limestones instead of the shale and sandstone and conglomerate we meet with elsewhere.

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* See Murray, Voyage of the Challenger.

In a sinking area many changes would be brought about by variations in the form of the ground which was being depressed, and the sediment would be sorted accordingly. Thus we find places where encrinite stems have been swept together with hardly any other organism among them; in another, great shells lie as they would best resist the current, with their edges buried and their round back only exposed, at other times the convex side is down and the white rim of the shell appears through the black mud. The result of all this is, that, although there is a general uniformity through hundreds of feet of limestone, when we examine the sections in greater detail, and look for characters that may enable us to recognise and trace the beds from place to place, we find differences of texture and structure often persistent over very considerable areas.

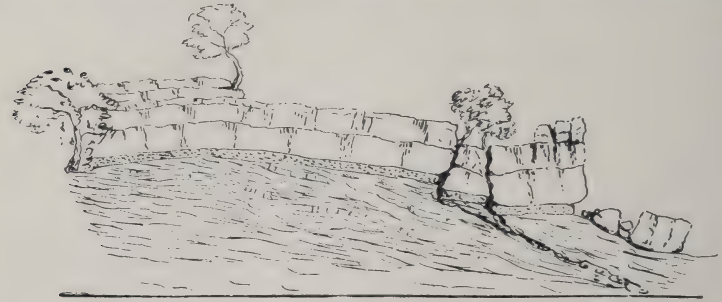

Fig. 1.

SECTION OF BASEMENT BEDS OF MOUNTAIN LIMESTONE ON BALA BEDS, BLACK ARK, NEAR THE HEAD OF INGLEBOROUGH TARN.

In the ascending section from Clapham, after crossing the fault at the head of the tarn, we start from the very base of the Mountain Limestone where it rests on the Bala Beds, near Black Ark. It is seen in a little stream which issues from a keld and runs into the head of the lake near the footbridge. There is no conglomerate seen at the base of the limestone, but only a yellow calcareous sandstone readily decomposed so as to exhibit a cavernous structure. It is much shattered and the fissures filled with calcite. The broken beds evidently communicate with feeders in the jointed rock, and caves are here in process of formation (see Fig. 1). Following up the main stream we find solid limestones in which the strongest divisional planes are those due to the bedding, and therefore we do not find the water cutting gorges along joints so much as tumbling over ledges, which it undermines and thus cuts back. Further up the valley we find this character conspicuously shown in the form of the caves, which here exhibit wide roofs of solid rock.

Caves and Swallow Holes.

It is because of this structure in certain parts of the limestone that we have such long galleries, running approximately at one horizon in the caves, and fed at intervals by deep chasms where master joints or faults have facilitated the descent of the water vertically through a great thickness of beds. There is often a slight parting of black shale or a clayey bituminous film between the beds, due to the crystallisation of the limestone which always tends to separate out the earthy or organic impurities along bedding planes or around nodular masses in which the crystallisation has been strong. Very large questions are opened up by the manner of occurrence of these caves.* The normal dip of the rock, small though it be, is to the north, and the natural course of the underground waters would be along the bedding, but the streams come out to the south where the ground suddenly falls along the great faults and an outlet has become possible.

When did those faults occur, and when did denudation take advantage of the lines of weakness produced by the faults to cut away the shales which once blocked the southern outfall, and when did the rain-water running off the highlands first reach the Mountain Limestone and begin to burrow into its depths by joint chemical and mechanical action ?

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* These questions I do not go into, but leave them to Captain Dwerryhouse and the other spirited explorers who have already done so much to elucidate the dark places of Ingleborough.

Many other very interesting geographical features, dependent upon the structure of the rock, can be observed in this area. The scars upon the Fell side, however they may have originated in far off ages, have been cut back to their present position by the action of ordinary sub-aerial denudation, including under that a good deal of rough work during the glacial episode. But the long cañon-like valleys with precipitous sides seem to be directly due to other causes. If we follow up Clapdale, for instance, we pass Ingleborough Cave on our left and see how easily the wide flat roof might break and let down the rocks above. Still more likely does it seem that the broader roof of the cave out of which the water now issues at a lower level should some day give way. Higher up the valley we find on our left, just before we reach Trowgill, a small gorge cut back into the hill, the upper or far end of which is full of broken limestone between which burrowing animals, such as badgers, foxes, and rabbits, have found access to the cavernous limestone behind. Water no longer flows out here except in great storms, when every joint and fissure of the limestone is full. This is obviously being cut back by the weathering of the limestone exposed in the gorge and above the cave. Immediately beyond this we come to Trowgill, which is a narrow gorge with precipitous sides in the upper part, but opening out into steep turf-covered slopes lower down. (Plates XXX. and XXXI.) Here we seem to have the mouth of a cave cut back, with the precipices broken down and rounded in the part which has been longest exposed. The floor of the ravine rises rapidly and the limestone closes across its upper end, showing that it is not an ordinary valley cut back by surface waterfalls and rapids. In the upper part, just before we get into the narrow passage through which we climb out on to the Fell, there are great horizontal openings between the beds like those seen lower down Clapdale. This gorge also looks like a cave cut back from its mouth. When we get out of the gorge we find ourselves in a narrow steep-sided valley, and, following it up, we see that its course is marked by swallow holes, such as that known as Bar Pot, just over the Fell boundary wall, or a little further on the celebrated Gaping Gill, which receives all the waters that collect on Clapham Brents and the " moist and squally ground " that forms a sort of bay between Ingleborough and Simon Fell.

Here we are dealing with a different stage in the same kind of denudation. This is not a valley which has been cut back and refilled, for we see horizontal limestone in many of the swallow holes, while the limestone over the adjoining area is often bent down towards the valley. It is not exactly the same as the cases just described where denudation has cut back from the mouth of the cave. In this case the roof of the cave has fallen in far beyond its mouth, causing settlements and cracks in the overlying beds and facilitating the engulfing of all water that may accumulate above. It is a similar case to that described by Phillips in explanation of the formation of Ease Gill Kirk.

If the surface water sinks down through one or many swallow holes in a depressed area, and finds its way out by subterranean passages, there may be no break-down along the line of flow, but the area in which the swallow holes occur may get more and more undermined by the local action where the acidulated and unsaturated water first reaches the rock. In this case the rock gets eaten back all round, sometimes in terraces so as to look like a great amphitheatre with its tiers of seats. Generally speaking, however, this feature is developed only for about three-quarters of the circumference, leaving a gap in the rim with an out-look to the lower ground.

A good example of this occurs between " John Ingleby's Wall " and where " Long Scar " is written on the six-inch map.

If we climb a little further north-east we shall find shallow depressions marking the incipient stages in the development of this feature, and if we drop over the scars into the north-west corner of Crummack Dale, under Capple Bank Wood, we shall see the extreme case where the whole of the limestone has been removed down to the impervious Silurian at the base.

Most of the great swallow holes of Ingleborough occur at the base of the Yoredale Rocks, where the water, which has collected on the higher slopes and is thrown off by the impervious shales, first reaches the jointed Mountain Limestone. They are sometimes a little in advance of the actual lowest beds, but in such cases the shale has been cut back so far since the pot holes were first formed, or masses of impervious drift have thrown the water forward a little way from the bottom of the slope. Gaping Gill referred to above is one of the most striking of these, and is of special interest owing to the explorations which have been carried on in it, and the certainty that it is the source of the water which issues in Ingleborough Cave.

About two miles further north and a little over half a mile west of Selside is the still more striking chasm known as Alum Pot. It is a good way from the top of the Mountain Limestone, but this is easily explained by the great masses of clay drift which cover that part of the mountain. For this reason also the swallow holes, which are numerous between this and Gauber at the north end of the Fell, enter the limestone at many different levels. Alum Pot receives the waters which collect on South House Moor and Borrins Moor in the bay between Simon Fell and Park Fell, and, like Gaping Gill, has received much attention from spelæologists.

On the east side of Ingleborough also, similar phenomena may be observed, but often with considerable variation, owing to difference of local conditions. For instance, Weathercote Cave is very near the base of the limestone and in consequence there is not the same great vertical extent of cavernous and fissured rock to contain the water in flood. Binder Scale Beck (which ordinarily enters the limestone at Long Slack, comes out again at Philpin Hole, and then plunges into Weathercote Cave) in heavy flood runs over the surface all the way and fills Weathercote to the brim. It usually issues a little below Weathercote House, and when the flat-roofed cavern known as Jingle Pot is not quite full, if the water is troubled, so as to lap against the roof of the cave, that and the compressed air make a curious gulping sound, from which the name of the place is derived. When ripples sufficiently high to touch the roof are not produced by the falling water within, waves may be produced by throwing large stones in, but of course when the chamber is quite full of water no sounds are emitted. All this chemical and mechanical underground denudation is perpetually going on ; even a boulder of limestone from the drift, when uncovered and exposed to the weather, in a very few years becomes fretted by the weather. The covering cake of soil held together by roots often conceals the operations taking place beneath it, till in some rainstorm the last supporting clod gives way and the surface soil and drift suddenly sink into the cavity which has been formed. Mr. Haythornthwaite, of Kirkby Lonsdale, told me that he had seen this happen here, about 100 yards west of the New Inn, where the ground suddenly sank and a swallow hole was formed before his eyes. South-south-east of the New Inn, on ground having the suggestive name of Keld Bank, there is another interesting exhibition of similar phenomena. Douk Cave is a huge chasm into which the waters from Southern Scales Fell once all plunged. The stream has been diverted and an interesting example of the rock having broken down over a cave can be seen.

Braithwaite Wife and Mere Gill Pot Holes and that named after Tatham's widow are similar to those above described, but Crina Bottom, above Ingleton, calls for more careful study. The black limestone which forms the uppermost portion of the Great Scar or Mountain Limestone, is seen in swallow holes along the breast of the hill above Red Gait Head, at about 1,500 feet above O.D., and runs south towards the intermittent stream known as Green Springs. This is now the principal feeder of Hard Gill, which runs into Crina Bottom. When we get down into the valley near the farm, at an elevation of about 1,150 feet, we find traces of alluvial deposits, first gravel three feet, on peaty mould three feet, then, in front of the farm, loam on gravel, while patches of alluvial deposits, derived perhaps from the overflow of the swallow holes, occur here and there all down the bottom of the valley. There is one large swallow hole known as Rantrey (? Rowantree) Hole, south of the farm on the opposite side of the valley, with a well close to it. It is curious to find torrential gravel and flood water loam in such a situation, where we should expect it would be all carried down into the swallow holes.

Round the south end of Ingleborough, even where the great masses of drift much obscure the section, numerous swallow holes still indicate the presence of the Mountain Limestone below, and reach it very near the top. In Fox Hole, for instance, north of Newby Moss, a little below the 1,500-foot contour, the dark grey, thin-bedded, fetid limestones, which represent almost the highest beds, are seen in the swallow hole.

But the most remarkable pot holes seen on this side of the hill are the two known by the same name, which, however, I will distinguish as Long Kin *East* and Long Kin *West* (see map).

Long Kin West is a chasm some hundreds of feet in depth, over which you can stand with one foot on one side and the other foot on the other side (see Plate XXXII., Fig. 1).

Having followed the great swallow holes round the hill we again start from Clapham and if, instead of following the stream, we take a higher horizon in the limestone, some 200 feet above the base, along the road to Clapdale Farm, soon after it leaves the track to Know Gap, we see, by the roadside near Monk Hole, outcrops of limestone in which the conspicuous divisional planes are inclined at a high angle to the South. In the quarry above the road the same thing is seen, and used to be much better seen than it is now since the quarry has been freshly opened out. These divisional planes have been taken for bedding, but bands of fossils make it quite clear that they are only strong joints inclined at an angle of about 80° to the bedding, the true dip being here about 7° in a northerly direction. This strong jointing is more constant to the bedding than to the horizontal, and, therefore, farther up the valley, where the dip is lower, the jointing is higher, so that in Trowgill the rock is divided into great platy slabs, which, when looked at endwise, give the effect of basaltiform structure (see Plate XXX.). There are cases in which systems of cross joints of nearly equal strength do give the rock an irregular columnar structure.

The Trowgill beds run up to about 1,000 feet above O.D. The precipice, as we have seen, is the side of a gorge probably due to a broken-down cave, though it happens to coincide with some of the most conspicuous "scars."

SCARS, AMPHITHEATRES, AND OTHER STRUCTURAL DETAILS.

The structure which seems most commonly to give rise to scars is the occurrence of rock, which splits chiefly along the bedding, resting upon rock which breaks more along the joints. For if the vertically-jointed beds are exposed they are apt to break off, covering the base of the precipice with talus and crumbling down the still exposed edge of the cliff (see Plate XXXIII., Fig. 1). There is never a vertical cliff behind the talus where the form of the surface would probably be, as in the case of a chalk cliff, parabolic,* a point which it is useful to bear in mind in cave hunting.

When, however, the jointed rock is capped with flat masses of unbroken limestone, perhaps with thin partings of impervious clay, they throw the water off, and the effect is to produce overhanging ledges from beneath which the more jointed rock weathers out.

The effect of these scars is well seen as we look out from Trowgill across the valley (see Plate XXXI.), and the bird's-eye view which we get from the higher ground further north enables us to see exactly the distribution and limitation of the higher beds left on the top of each spur. For here there are thinner beds of a light grey limestone occurring sometimes in a tabular mass with steep sides, but more often, especially in the lower part, chamfered off all round. In these fossils are fairly abundant, *Chonetes* being especially conspicuous as the rock splits along its flattened white shell. *Producta Martini* and *P. striata* occur here also.

A little above 1,200 feet contour, on the way to the path among the Long Scar clints which is known as Clapham Lane, there is another example (see Plate XXXIII., Fig. 2), on a much smaller scale, of the tabular bedded limestone resting upon vertically jointed rock, and forming a marked feature for some distance. The boy, holding a five-foot alpenstock, gives the height. Above this we rise by steps and terraces almost to the top of the Grey Mountain Limestone, which extends irregularly in bare, joint-riven, weathered rock from 1,200 to 1,300 feet above O.D., sometimes a little more, sometimes a little less, according to the original foldings of the strata, the sinkings due to underground waters, and the irregularities of surface denudation.

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* cf. Fisher, Geol. Mag., Vol. III, 1866, p. 354.

To follow up the section still further we may pass on to the bed of the stream which runs down from the sandstone at the top of Farrer's Allotment by the Shooting Box to Sulber. The Mountain Limestone everywhere yields along the bedding planes, so as to give rise to the bare jointed surfaces locally known as "clints" or "helks." This is especially the case near the top of the Great Scar, where the overlying Yoredale shales are apt to be removed wholesale.

The terraces thus formed catch on their fissured surface all the water that runs off the steep slopes of Carboniferous Shale or Boulder Clay above, and discharge it in springs and kelds, where it is arrested by impervious strata below. Thus we find on the top, swallow holes, at the base, caves.

This happens also to some extent in the case of every subordinate limestone in the Yoredale Series, which can frequently be traced—the upper boundary by the lines of swallow holes, and the lower boundary by the springs along the hillside where the limestone itself is buried under superficial deposits. We see on these extensive floors of bare limestone the pattern of the jointing, and how the presence of vegetation and water running off peat aids the chemical decomposition of the rock along the joints. (Plate XXXIV., Fig. 1, shows the margin of the clints west of Sulber, where denudation is most rapid owing to the action of the acidulated water from the adjoining peaty moor. The figure is standing on one of the long blocks of limestone between the master joints, which are weathered into various forms like procumbent statues or the tracery of a Gothic window. He is pointing to the place where the Sulber fossils mentioned on p. 275 were procured. Behind him higher strata, but still belonging to the Great Scar, are seen creeping over the bed on which he stands, showing that these clints are not the highest beds of the Great Scar Limestone. Penegent is seen in the distance.) We know that the surface of the beds is similarly removed, often leaving pedestals of the unweathered rock on which glacial boulders are perched (see Plate XXXIV., Fig. 2). In some cases glacial striæ are still preserved upon the surface of the rock on which they rest. These must not be confounded with the undercut blocks of limestone which stand there in their original position owing to the removal of the intermediate rock that once extended continuously over the whole area (see Fig. 2). The limestone weathers along joints, and the corners and edges of the isolated blocks are rounded off, as in the case of the grits of Bramham Moor or the granites of Cornwall. On the north-west side of Ingleborough, above Sleights Pasture, there are many good examples of this, showing the manner in which Logan Stones, Perched Blocks, and similar phenomena are produced.

We have seen how, under certain conditions, the sand and boulders, hurried along by water, help mechanically to carry away the rock. But there is another very interesting phenomenon to be seen sometimes when flood-water is driven along with great velocity over the jointed face of limestone, such as occur below Ingleborough Cave or above Gaping Gill. The joints and the lines of weakness between two beds are opened out, or perhaps a shaley parting removed. The limestone then lies in large detached slabs fitted together so closely and so deeply that they could not be lifted out by any ordinary operation. They rest on concretionary lumps which allow a large body of water to be in contact with the lower surface of the slab and in communication through the joints with the body of water coming down stream. When in flood-time the volume and velocity of this is increased, the pressure on the small area of water in the joints is multiplied by the hydrostatic paradox over the under

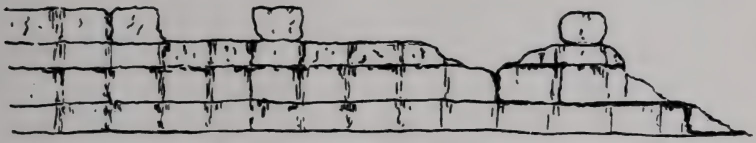

Fig. 2.

BLOCKS OF LIMESTONE ISOLATED OWING TO THE WEATHERING AWAY OF THE SURROUNDING PART OF THE BED. SLEIGHTS PASTURE, N.W. OF INGLEBOROUGH.

side of the great slab of limestone, and it is lifted out and hurled along. I have sometimes seen in Dent, after a flood, a great slab left, here and there, on end at the down-stream side of the joint-bounded cavity from which it had been lifted out.

These manifestations are of especial value to the ever increasing band of spelæologists who are doing so much to elucidate the formation of caves and the course of underground waters in cavernous rocks. If we see an ordinary spate lifting a slab four feet square out of a cavity one foot deep—say 1,000 lbs. weight of rock—what must be the effect of the water in Gaping Gill which would have a dead weight of 10 atmospheres when the chasm was full and an intermittent thud due to the velocity proper to the depth as the water was subsiding in it?

As might be expected from the character, condition, and lie of the Mountain Limestone in this district, the phenomena connected with its springs are very varied and interesting. The rock is traversed by joints and faults which are opened out first by chemical action of the water holding carbonic and other acids in solution, and then by its mechanical action as it carries along boulders and grit and mud. A network of caves is thus formed along the fissures, and when there has been an exceptionally heavy rainfall the lower outfalls are unable to carry off the surplus water, which then finds its way out through old deserted channels at higher levels. But the outcome of it all is that the flood occasionally rises in the creviced rock and produces a head of water, which comes out through the small openings at the base or on the sides of the rock under enormous pressure. But in some cases the water does not come to the surface directly from the fissures in the limestone, but finds its way into permeable strata which abut against it, as, for instance, where a limestone talus or a bed of gravel lies at the base of a limestone cliff. The springs in such a case are thrown out where the permeable strata end, and, if a wash from Boulder Clay, or the clayey residuum from decomposed limestone overlaps the permeable strata, the water may burst out anywhere.

In Jenkin Beck, east of Ingleton, some very curious springs are thus produced. Here a fault throws down shales belonging to the Yoredale Series against the Mountain Limestone. A stony talus extends from the face of the limestone cliff over the impervious floor provided by the shale. A covering of travertine and clay from various sources covers the talus and overlaps on to the shale. In flood-time, when the crevices of the limestone are full and the talus is charged to bursting point under the pressure due to the head of water in the limestone, the springs break through here and there, where the clay covering is thinner or other conditions favour the outburst, and jets of water, sometimes as much as two feet in height, issue from the ground. These springs carry carbonate of lime in solution, and mud and sand and gravel in suspension, and throw both down around the opening so that a mound, like a volcanic cone, is built up, on the top of which is a perennial or intermittent spring of water (see Diagram, Fig. 3).

As a result of all this chemical wasting away of the limestone, the water that issues from the caves and springs is very hard, and when aerated, the lime, which it had held in the more soluble form of a bicarbonate, is thrown down, forming the masses of stalactite and stalagmite that line the caves, and the patches of travertine that so often help us to find the position of the limestones on the flanks of Ingleborough.

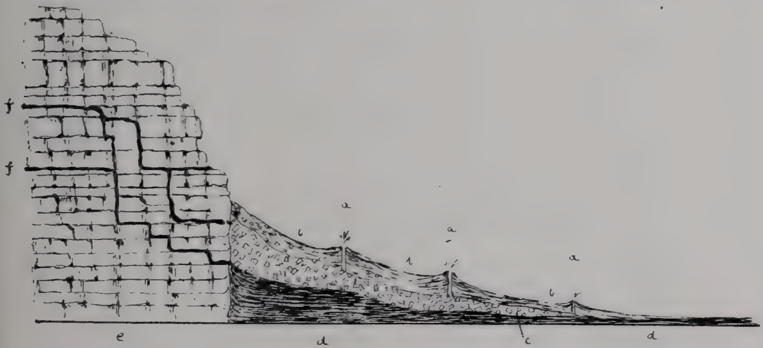

Fig. 3.

DIAGRAM ILLUSTRATING THE MODE OF FORMATION OF THE CONE SPRINGS IN JENKIN BECK, EAST OF INGLETON.

a. Springs.
b. Clayey deposit from springs and rainwash from hillside.
c. Stony talus.
d. Yoredale shale.
e. Mountain limestone.
f. Watercourses in limestone.

When this hard water is collected in hollows and pans and tarns, sometimes it becomes supersaturated by evaporation and the lime is thrown down ; sometimes the process is aided by the action of chara and other lime-collecting plants ; sometimes fresh-water shells help to form the marl that is so commonly found in peaty hollows fed from the limestone hills. One of these lying on the old uneven Silurian floor in the middle of Crummack Dale offers an example of all these agencies combined. The following shells were identified in it by Mr. Hughes during one short visit :—

Sphœrium corneum.
S. pusillum.
Planorbis nitidus.
Limnœa peregra.
L. palustris.
Valvata cristata.
V. piscinalis.
Succinea putris.

FOSSILS OF THE MOUNTAIN LIMESTONE.

In the lowest limestone above the basement conglomerate fossils are not scarce. They are abundant in the cliff where the water comes out that crosses the Crummack road at its lowest part. Mr. Clapham has recently made an opening here in the weathered limestone just above the conglomerate, and fossils are easily procured from the broken rock. The following species are common :—

Euomphalus pentangulatus.
Bellerophon (of very large size).
Chonetes comoides.
Zaphrentis cornucopiœ.
Amplexus.
Caninia cylindrica.
Lithostrotion basaltiforme.
Michelinia megastoma.
Syringopora.
Producta Martini.
Spirifera glabra.

In the Ingleton quarries, although the rock is here wedged in between two great faults, we know that we are not very far from the base as it is seen in the stream below. The fossils we have recorded from these beds are *Bellerophons* up to five inches across the mouth.

Producta cora.
P. striata.
P. Martini.
Chonetes papilionacea.
Cyathophyllum Murchisoni.
Amplexus.

In Robin Proctor's Scar (see Plate XXXIII., Fig. 1) I have found—

Producta striata (Fischer).
P. fimbriata (Sow.).
P. punctata (Mart.).
Spirifera [*Martinia*] *glabra* (Mart.).
Athyris expansa (Phill.).
Orthis [*Schizophoria*] *resupinata* (Mart.).
Streptorhynchus [*Orthotetes*] *crenistria* (Phill.).
Cyathophyllum.

In Thwaites Scar fossils are fairly abundant, and as among them we find *Dibunodon* and *Producta Martini*, and a little higher *Chonetes papilionacea*, *Lithostrotion Portlocki*, and *Alveolites septosa*, as well as many forms of wider and longer range, such as *Spirifera glabra*, it is obviously a great help to be able to trace this horizon by such a conspicuous feature as these scars present.

In the grey limestone of the Great Scar, on the northern part of Sulber (see Plate XXXIV., Fig. 1), near Simon Fell Nook, I found the following species :—

Producta semireticulata (Mart.).
P. longispina (Sow.).
P. pustulosa.
Spirifera [*Martinia*] *glabra* (Mart.).
Sp. bisulcata.
Sp. pinguis (Sow.).
Sp. trigonalis (Mart.).

Chonetes hardrensis (Phill.).
Athyris Roysii (l'Ev.).
Pinna.
Actinoceras Breynii (Mart.).

Producta striata is especially common in certain beds on Sulber, near the top of the Great Scar Limestone.

On the highest part of these terraces we find, here and there, a patch left of the dark grey impure limestone, which forms the passage bed up into the black rocks, which are sometimes known as the Gayle Limestone. In these passage beds the same species of *Phillipsia* and *Griffithides* occur as are found more plentifully at the same horizon in Flintergill, just above the old Vicarage of Dent.

THE BLACK MARBLE AND SHALEY LIMESTONE.

Between the contours of 1,300 and 1,350 the grey limestone has been all traversed, and there is probably a thin bed of shale which is now covered by drift and tumble between it (i.e., the grey limestone) and the black shaley limestone (*f* and *g* of Fig. 4). But at the bend of the stream, 400 yards south-east of the Shooting Box, the water falls over several ledges in which the black limestone is well exposed (see Fig. 4), and in some thin, nodular, clayey beds much undercut, below the lowest fall, *Producta gigantea** occurs in abundance. With it are found *Producta hemispherica* and corals belonging to the genera *Lithostrotion*, *Cyclophyllum*, *Zaphrentis*, *Lonsdaleia*, &c.

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* I follow Jukes in the spelling of these words :—" A fashion," says he, " has lately crept in of calling this *Productus*. It seems to me we might as well speak of a *Terebratulus*, an *Atrypus*, or a *Rhynchonellus*. Where a Latin adjective is employed as a name of a bivalve shell, it should always be made to agree with Concha or Cochlea understood, and only have a masculine or neuter termination when a substantive is used as *Pentamerus*. The shell was originally called *Anomia producta* and afterwards *Producta* alone ; why not let it remain so ? " Of course Jukes' remarks apply also to words of Greek origin which we use in a Latin form.—A Student's Manual of Geology, 2nd Edition, 1862, p. 536.

In respect of the use of capital letters in specific names, I follow the advice of Mr. Cowper Reed in the Sedgwick Museum. When the genitive of the substantive proper name is employed, we use a capital initial, but, when the specific name is an adjective derived from the proper name, we write it with a small initial letter.

There is also a well-marked band full of small yellowish concretions formed round organisms which I will refer to as the "almond" bed.

It is probable that there are beds of shale concealed under the superficial deposits between these Lower Black Limestones (*f* and *g*, Fig. 4), and those (viz., *b* and *c*) which crop out in the bed of the stream above where the wall (*d* of Fig. 4) crosses it. These Upper Limestones (*b* and *c* of Fig. 4) are very different in character and contain a different fauna. The rock, especially the highest beds seen (*b*), consists of fine, thin-bedded, black limestone, which takes a good polish in the bed of the stream where the sand from the beds above is carried over it. It weathers to a small depth into a white or dun surface, on and from which the fossils, having a different texture, stand out in dark relief. In this occurs a strongly involuted form of *Producta* (see Plate XXXVI., Figs. 1 and 2), with a very long hinge line and uniform, sharply defined, relatively broad ribs. This is *Producta latissima* described by Phillips,* and marks a different

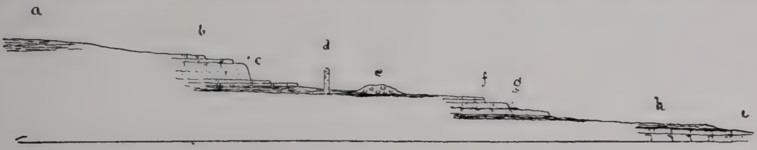

Fig. 4.

DIAGRAM OF SECTION SEEN IN GILL BELOW FARRER'S SHOOTING BOX.

	a.	Shale seen in bank above road by stream.
LATISSIMA ZONE.	*b.*	Black Marble in thin beds.
	c.	Black Marble in thicker beds over which there is a small waterfall (Plate XXXV., Fig. 1).
	d.	Wall crossing stream.
	e.	Boulder Clay with scratched stones.
		There is probably shale below *d* and *e*.
LOWER GIGANTEA ZONE.	*f.*	Black Bituminous Limestone in thick beds causing small waterfalls.
	g.	Black shale and Nodular Limestone with *Producta gigantea*.
		Shale seen below the Lower Gigantea Zone in adjoining sections.
TRILOBITE ZONE.	*h.*	Black Limestone in irregular slabs seen along the wall to the south.
	i.	Grey Massive Limestone.

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* Geology of Yorkshire, Pl. VIII., Fig. 1.

horizon from that (*g* of section, Fig. 4) characterised by the large specimens of the normal form of *Producta gigantea* which occurs further down stream (see page 276). The Upper or Black Marble Series occurs in thicker beds as we follow it down stream (*c*, Fig. 4), and, in consequence, instead of producing shallow wide ledges, gives rise to small gorges through which the water rushes in cascades, as is well seen in Plate XXXV., Fig. 1.

This rock is on the same horizon and has much the same character as the Black Marble of Dent. In fact, where the quartzose sand of the overlying series is carried by the stream over the surface, these beds are beautifully polished and curious effects are produced owing to the interruption of the current here and there by small grains of harder material or protuberant fossils whose crystalline texture better resists the action of the sand and water.

Flint occurs abundantly, especially in the higher beds, and a new fracture shows clearly the marginal portion of the segregations which is generally of a lighter colour than the black limestone in which it occurs, or the blacker flint within. These marginal portions probably represent the limestone imperfectly replaced by silica, and to them the term "chert" would be more properly applied than to the black nucleus.

It seems to me that a very important change sets in between the Lower Series of Black Limestones, with the large normal *Producta gigantea*, and the Upper Black Marble Series, with *Producta latissima*, Phil., and I would feel inclined if I were drawing a line in a new country to take the base of the Yoredale rocks between these two, viz., at the base of the shale, between the Upper or Black Marble and the Lower or Black Shaley Limestone Series. This, however, is not a matter of very great consequence, for I quite agree with what Salter used always to tell me, that the Yoredale rocks were but the splitting up of the top of the Mountain Limestone. If this be so, we may expect considerable variation in detail from place to place, though the general characteristic is that the top of the grey limestones of the Great Scar begin to show more and more carbonaceous and clayey material, and sometimes one, sometimes another, kind of sediment predominates in different, but often not widely separated, areas—and, of course, the fauna shifted about seeking congenial habitats on a changing sea bottom.

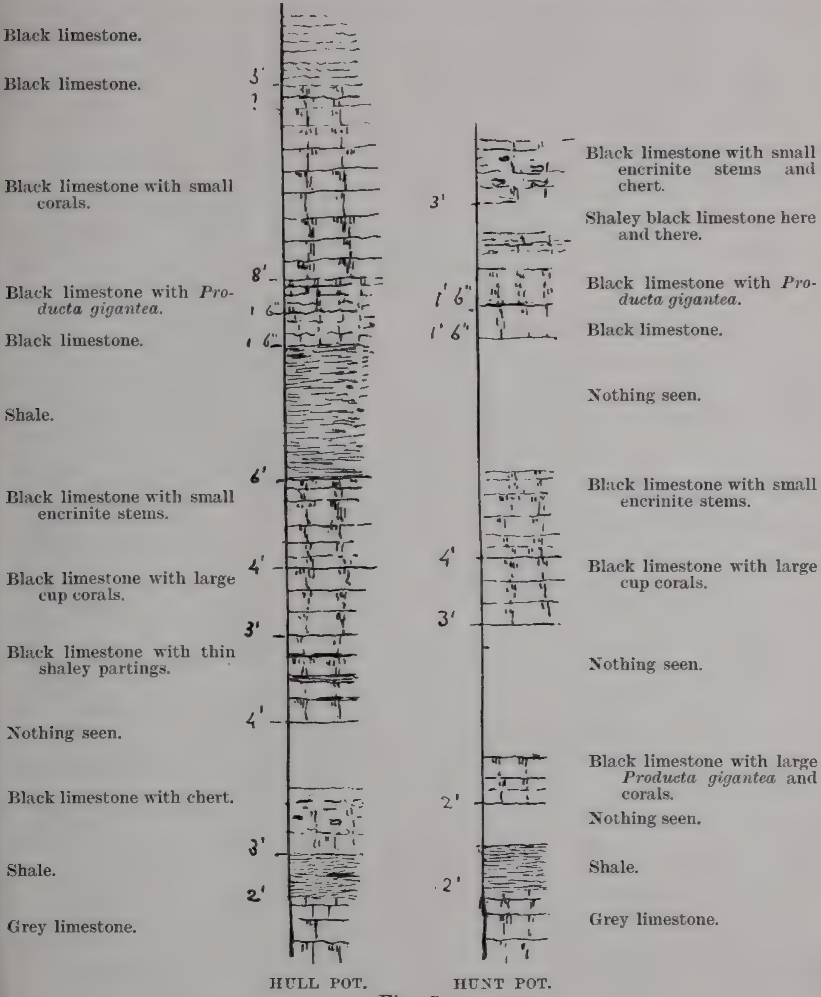

Black limestone.
Black limestone.
Black limestone with small corals.
Black limestone with *Producta gigantea.*
Black limestone.
Shale.
Black limestone with small encrinite stems.
Black limestone with large cup corals.
Black limestone with thin shaley partings.
Nothing seen.
Black limestone with chert.
Shale.
Grey limestone.
3'
?
8'
1 6"
1 6"
6'
4'
3'
4'
3'
2'
3'
1' 6"
1' 6"
4'
3'
2'
2'
Black limestone with small encrinite stems and chert.
Shaley black limestone here and there.
Black limestone with *Producta gigantea.*
Black limestone.
Nothing seen.
Black limestone with small encrinite stems.
Black limestone with large cup corals.
Nothing seen.
Black limestone with large *Producta gigantea* and corals.
Nothing seen.
Shale.
Grey limestone.
HULL POT.
HUNT POT.

Fig. 5.

Anyone who wishes to work out the relations of these beds would do well to examine carefully the section in Flintergill, Dent, and those exposed in and near the two great swallow holes known as Hull Pot and Hunt Pot (see Fig. 5), which occur close together under the western slopes of Penygent, that is to say, on the nearest place where the top of the Mountain Limestone is exposed east of Ingleborough. There is often some confusion about the names of these two swallow holes; Hull Pot is the northern, and Hunt Pot the southern chasm, the distance between them being about 600 yards.

From the black limestones above Hull Pot I have procured the following species, but they were collected before I had cut off the Black Marble Series above from the Black Shaley Limestone Series below, and the list therefore includes the fossils of what I now consider two distinct horizons:—

Producta gigantea (Sow.).
P. costata.
P. semireticulata (Mart.).
P. aculeata (Mart.).
P. punctata (Mart.).
P. scabricula (Mart.).
P. cora (d'Orb.).
P. longispina (Sow.).
P. longispina var. *lobata.*
P. fimbriata (Sow.).
Spirifera (*Martinia*) *glabra* (Mart.).
Sp. striata (Mart.).
Sp. lineata (Mart.).
Sp. trigonalis (Mart.).
Sp. grandicostata (McCoy).
Sp. crassa (de Kon.).
Sp. bisulcata.
Sp. humerosa.
Sp. margaritacea.
Spiriferina octoplicata.
Athyris Roysii.
Streptorhynchus [*Orthotetes*] *crenistria* (Phill.).
Orthis Michelini (l'Ev.).
Camarophoria crumena (Mart.).
Actinocrinus.
Lonsdaleia floriformis.

Lithostrotion irregulare (Phill.).
L. basaltiforme (C. and Ph.).
L. junceum (Flem.).
Cyathophyllum turbinatum.
Dibunophyllum sp.
Syringopora ramulosa (Goldf.)
Clisiophyllum.
Pinna flexicostata.
P. flabelliformis (Mart.).
Lamellibranch like *Anthracosia.*
Fenestella quadridecimalis.
F. Morrisii.
Spirobis carbonarius.
Bellerophon.
Naticopsis.
Orthoceras.

In the bed of the stream above Hull Pot *Producta gigantea* occurs in great abundance and of great size, and there is also the same variety of *P. costata*, with very strong longitudinal ribs, which we noticed about the same horizon in the bed of the stream below Farrer's Shooting Box. We have here also, near the mouth of the chasm, the same thin band of almond-like concretions coating organisms which we found below Farrer's Shooting Box. Above Hull Pot the black limestone, with *Producta gigantea*, is exposed in the bed of the stream, and the large white shells lying back downward in the black shaley rock explain the local name, " horse shoe limestones," by which this and similar beds are known in the dales, and remind us of the " Rocca delle Stampe " above Tremezzo, on the Lake of Como, where sections of the great Megalodon produce a similar effect, or of the " Versteinerte Herzen " or " Hirsch tritte " of the German Dachstein.

In Fell Close Sike, 700 yards north of Farrer's Shooting Box, and due west of Simon Nook, we find 35 feet of black limestone with chert and large *Productas*, below which shale is seen to six feet in thickness, and then more black limestone just above where the water enters the swallow hole. Many years ago Townsend, M. Hall and I collected a large number of fossils from the black limestones and shales at the top of the Mountain Limestone in Fell Close Sike. I do not know what has become of that collection now, but I give the list which we then drew up, as it will at any rate suggest to others what to look for, even if they should more than once have to suggest a mistaken identification.

Fenestella antiqua.
Lithostrotion irregulare.
Syringopora ramulosa.
Aulophyllum fungites, Ed. and H., Pl. 37, Fig. 3. = *Turbinolia fungites*, Phill., p. 203.
Spirifera glabra.
Spirifera, a coarse ribbed sp.
Streptorhynchus [*Orthotetes*] *crenistria.*
Producta scabricula.
P. pustulosa.
P. semireticulata.
Orthis (*Schizophoria*) *resupinata.*
O. Michelini.
Pinna costata.
Sanguinolaria sulcata ?
Euomphalus.
Phillipsia Brongniarti. (*Asaphus obsoletus* or *A. granuliferus* of Phillips.)

And a fragment of fish, respecting which Townsend Hall afterwards wrote to me, "*Petalodus Hastingsiæ*, Ag., p. 468, Plate XIV., Fig. 10, unlike figure in Owen's 'Odontography.'" Plate XXXV., Fig. 2, is a sketch I made of it at the time.

I shall have to refer again to the fossils of this horizon in discussing the remarkable recurrence of identical species in the Main or Upper Scar Limestone (see pp. 298, 299 inf.).

A little more than 200 yards still further north another section exhibits black limestone with chert, and very large encrinites in black limestone with productas, and then after a small interval more black limestone.

From this point we trace the black limestones which form the uppermost beds of the Great Scar by small indications to the streams which empty themselves into Alum Pot. The section, as we come down South-house Moor Beck (Fig. 6), throws much light on those previously observed as we follow this horizon where small alluvial patches indicate gentler slopes. Below the "Stepping Stone" (marked on the old edition of the six-inch map), the first rock we meet with is a black limestone with chert; lower down still there is a similar limestone which is

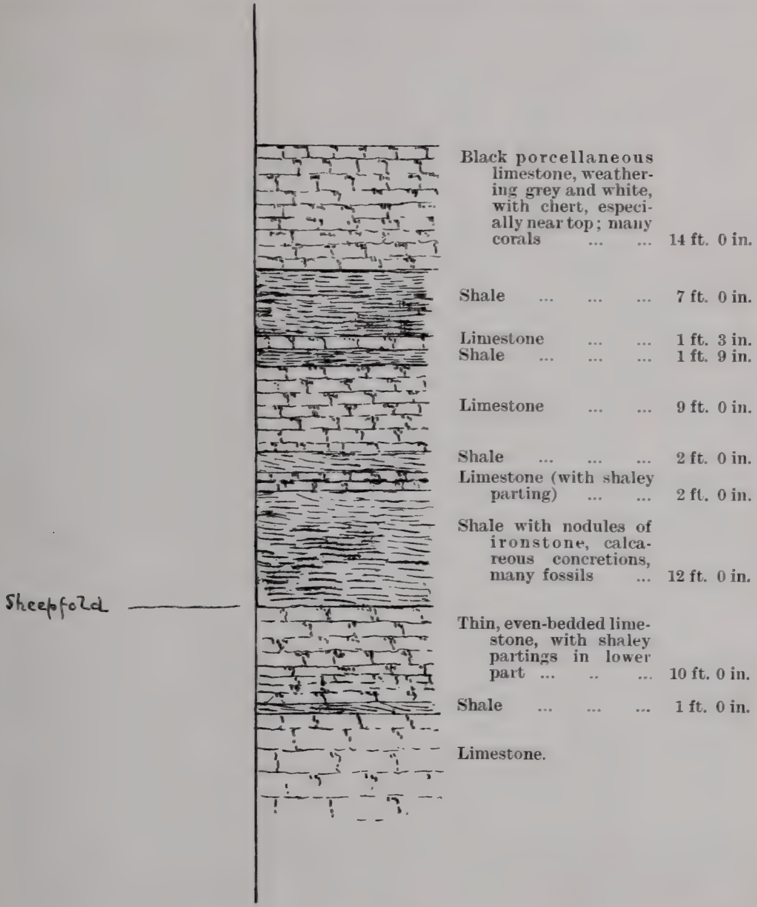

Black porcellaneous limestone, weathering grey and white, with chert, especially near top; many corals ... ... 14 ft. 0 in.
Shale ... ... 7 ft. 0 in.
Limestone ... ... 1 ft. 3 in.
Shale ... ... 1 ft. 9 in.
Limestone ... ... 9 ft. 0 in.
Shale ... ... 2 ft. 0 in.
Limestone (with shaley parting) ... ... 2 ft. 0 in.
Shale with nodules of ironstone, calcareous concretions, many fossils ... 12 ft. 0 in.
Thin, even-bedded limestone, with shaley partings in lower part ... . 10 ft. 0 in.
Shale ... ... 1 ft. 0 in.
Limestone.
Sheepfold

Fig. 6.

SECTION SEEN IN LOWER PART OF SOUTH HOUSE MOOR BECK, INGLEBOROUGH, NEAR THE SHEEPFOLD AND WASH DUB.

20 feet to 1 inch.

full of fossils, *Syringopora* and *Lithostrotion* being especially conspicuous; close by there is a close-grained limestone—black marble in fact—weathering white. Below this there is more black limestone with shale in it, and a bed of shale at its base separating it from the grey limestone of the Great Scar.

In this section we seem to have the same sequence as that described above, in the stream below the Shooting Box, only here we see the subordinate shales which were there only a matter of inference or conjecture. Here, where we find the sequence of beds from the grey limestone of the Lower Scar to the Black Marble Series well exposed, no fewer than five beds of intercalated shale can be detected, which fully justifies the suggestions made above in respect of the section seen below Farrer's Shooting Box, namely that the Upper or Black Marble Series was separated by shale from the Lower or Black Shaley Limestone Series, and this again by another shale from the grey beds in the top of the Great Scar.

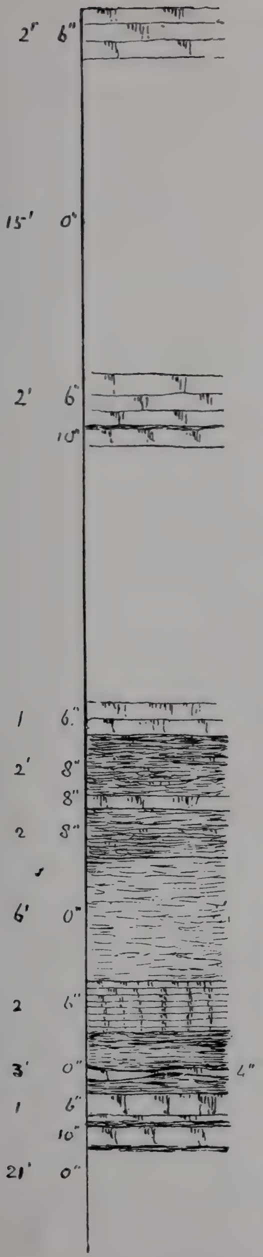
The great mass of drift gathered in the embayed slopes of South-house Moor has collected the drainage from the steep slopes as far south as Borrins Moor, and now empties it into Alum Pot, while Whitagreen Spring and Long Churn Spring drain the slopes further north and feed the swallow holes which now catch much of the water that must once have plunged into Alum Pot. Many a beautiful cave and many a yawning chasm tell of the changes that have taken place in the drainage of this hill-side as the drift and shale were being cut back. The black limestones can be traced north, by swallow holes and small exposures of limestone and shale in the streams that feed them, here and there up to Gauber High Pasture, where there are many sections through different parts of the series, the streams frequently entering the limestone through a bed of shale, which must have fallen in over broken-down caves. The northerly dip affects the denudation, and, of course, from its making the beds extend over a greater horizontal distance, gives the impression that the series is thicker than it really is. Near High Barn there is a dark grey limestone with chert, and below it shale, well seen in the wood at the spring head above Colt Park, which is called from this Shiver Plantation, "shiver" being a local word for shale or other crumbly rock. About 500 yards west of Colt Park there is a brown earthy limestone with plants, and higher up the hill a cherty limestone with small corals and *Cauda Galli* markings. These beds have not been worked, but seeing that they are in the Black Limestone Series, they are of exceptional interest, as the horizon is exactly known, and these plants are very low down in the Carboniferous group.

Following the same horizon round the north end of Ingleborough and along its north-west flank, we find black limestone and shale in the streams which run from Fairweather Springs. Along this terrace all the best caves and swallow holes occur, as it is here that the streams which gather on the flanks of the mountain first reach the Great Scar Limestone. Fortunately, however, the water has often undermined and let down the overlying drift and shale, and given us good sections in the Black Limestone Series, which is the most interesting part. For instance, in the stream from Keld Bank Spring we find first a black limestone with chert and abundant fossils, and, after a small interval of eight feet, more black limestone resting on black shale, below which again there is eight feet of limestone full of small encrinites, then about four feet of shale. Below this the black bituminous limestone, which forms the top of the grey beds of the Great Scar, is often séen in swallow holes, and we can trace this horizon in small sections for about a mile and a half to the south-west, where we find the magnificent swallow hole which receives the waters which have gathered in the deep bay where Humphry Bottom and Black Shiver Moss lie in the shadow of the highest point of Ingleborough. In this grand chasm we see the grey limestone of the Great Scar capped by black bituminous beds, which should be searched for trilobites. The shale is obscured by drift, but a little higher up there is a black limestone with many small corals and chert, then about four feet of shale, above which there is more black limestone, full of productas.

The ground is now heavily covered with drift for a mile and a half to the south, but still in the pot holes, here and there, we find black bituminous limestone resting on the grey beds of the Great Scar; in Tatham Wife Hole, for instance, or above

Red Gait Head, or in the pot hole on Newby Moss that receives the waters of Grey Wife Sike.

And now, having made a circuit of the mountain, we get round on the south side of Ingleborough to perhaps the most interesting example of the waters of a steep embayed area being collected, engulfed, and thrown out below. For grandeur and beauty Gaping Gill is far surpassed by more than one of the swallow holes mentioned above, and for the study of the succession and fossil contents of the uppermost part of the Great Scar it does not offer nearly as favourable opportunities as those which occur further north, but it is the most accessible, has been most explored, and exhibits some of the phenomena of denudation in a manner that cannot often be seen. The succession also is not nearly as complete as in some other sections at this horizon (see section, Fig. 7). *Producta*, *Spirifera*, *Zaphrentis*, *Lithostrotion*, and *Syringopora* are fairly abundant, but it is not so easy to extract them from the rock here as in many other sections at this horizon. As we look north from the top of the great mass of drift, through which the water has cut the valley which is now tapped half way down the fell by Gaping Gill, we see a small river and its tributaries all complete before our eyes. The steep slopes of Ingleborough on the left are drained by Riggs Sike, Sware Gill Sike, and Thack Pot Sike, which runs in close above Gaping Gill. Right in front of us the longest feeder, Green Hill Sike, rises on Simon Fell Breast and, catching the waters of Wet Weather Sike and many a nameless runlet, soon asserts its right to be considered the principal stream, in the depth of its valley and the body of water which it carries. When it really "rains between the showers" on Ingleborough, the water is not confined to these small channels, but streams down over the steep crags and the drift and peat-covered slopes. Where it does get collected into the watercourses, the effect of such heavy bodies of water running down on such a slope is to tear away the superficial deposits and the jointed rock, and to make gashes along its course in every flood. As much of this ground consists of Boulder Clay, large blocks are hurled along the bed of the stream, grinding and bruising the surface of the limestone in its course. When they reach Gaping Gill



Limestone.

Crushed shale seen here and there.

Limestone with fossils.

Shale parting
Limestone.

Nothing seen, probably shale with subordinate limestones, of which traces are seen here and there.

Limestone with Orthis.

Shale with subordinate limestones; fossils abundant. Brachiopods, Corals, and Encrinites.

Subordinate limestone with large specimens of *Producta gigantea* and *Zaphrentis*.

Shale with subordinate limestones; fossils abundant. Brachiopods, Corals, and Encrinites.

Shale.

Black cherty limestone weathering white.

Crushed shale with subordinate lenticular bed of limestone to 4″ full of *Syringopora*.

Dark grey limestone with large corals.
Cherty crystallinefetid limestone with a few inches of shale at base nipped out.

Limestone with a thin parting of shale at the base partly nipped out.

Grey limestone seen above Gaping Gill, a band of darke limestone near the top full of small Encrinites.

The depth of the hole as plumbed in one vertical descent from the turf to water at the bottom, 360 feet.

Fig. 7.—SECTION SEEN IN GAPING GILL.

their velocity is so great that they strike the opposite side of the chasm with such momentum that after a great flood the rock is seen to be bruised all over, teaching us that a great part of the subterranean denudation is due to the action of boulders and pebbles upon the rock, which is here battered by fragments bounding from side to side with ever increasing velocity in their long descent of over 300 feet. This was especially conspicuous after the great flood of 1872, and the pounding up of the black limestones was also curiously forced upon our notice in another way on that occasion, for the people down the valley at and below Clapham observed that a strong gas-like smell arose from the flood—I suspected its origin and, as the water fell, found that an enormous quantity of black sand had been brought down. On rubbing this between my two hands I found that it gave off the same fetid smell which had been noticed. This was very remarkable, for, on that occasion, the water had passed through the tarn, but the air tangled in that seething flood had not time to escape even there. We must, however, remember also that the volume of water was so great that it produced a considerable current even in the deep waters of the tarn, and perhaps some of the mud, with decomposing vegetable matter from dead leaves, &c., may have got stirred up and contributed its share of carburetted hydrogen to the tangled air.

Cautions and Suggestions.

We have often to run a very cold scent along the flanks of Ingleborough, and as a good deal depends upon our trusting to persistence of dip, thickness, &c., in tracing the various subdivisions of the Yoredale rocks under the drift and peat bogs, a few words of caution bought by experience may be helpful. When following an obscure boundary line among beds which are not easily distinguished from one another, as is the case among the black limestones of Ingleborough, it is very easy to drop or rise from one formation to another similar one in crossing a swampy tract of peat or drift, or a rough bank of talus. Supposing, for instance, we are going north along the east flank of Ingleborough (see Fig. 8), where the beds *ab*, *cd*, *ef*, are sloping almost imperceptibly to the north, and we start at "*a*" and try to trace the limestone *ab*. The bottom of the valley is rising and the slope increasing from *G* to *H* ; the effect of this is to make us rise continually and take the path indicated by the dotted line *af*, so that finding indications of limestone at *c* and again at *f* we draw our boundary along *af*. I have known one of our very best field geologists led on to the second limestone above that on which he started by this source of error, which is a kind of optical delusion.

To avoid it it is necessary on such ground always to carry an aneroid barometer, or better a pocket level, by which observations can be taken on fixed objects in front with sufficient accuracy to prevent our travelling up when we think we are going down, or *vice versâ*.

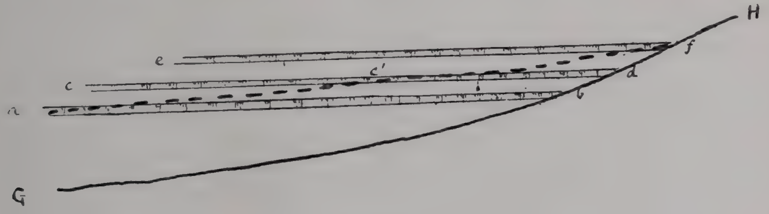


Fig. 8.

DIAGRAM EXPLAINING A SOURCE OF ERROR IN RUNNING BOUNDARY LINES ON INGLEBOROUGH.

There are some small faults on Ingleborough which are generally quite easy to detect and trace. Some of them seem to be cracks in the Carboniferous rocks recurring over pre-existing lines of disturbance in the underlying Silurian and Bala Beds. Some, occurring as they do on such a bluff as Ingleborough, justify our inquiring whether they may not be analogous to the "marginal effects" of earthquakes.

But interesting as these are, and wide as may be the field of inquiry suggested by them, the irregularities of dip which are practically the most important for us on Ingleborough, are those sudden changes of direction and amount over areas of limited extent to which I have frequently had to refer. As, for instance, in the case of the converging dips round swallow holes where the rock is breaking down into the gradually eroded hollows and scars are cut back, forming the beautiful terraced amphitheatres to which I have called attention as occurring here and there on the way up to the top of the Mountain Limestone. Then again we have the broken-down cave, which is the same thing only of a different form.

But we must be on the look out for another cause of disturbance in the surface strata, especially when we are following the boundaries of the rapidly alternating strata of the Yoredale Series. At Dale Head, in Dent, the Black Marble was quarried down to the impure bed forming the passage between it and the underlying shale. When any considerable surface of this thin bottom bed was exposed it was often found to be thrown into a state of tension, owing to the compression of the shale by the enormous superincumbent weight of rock on either side, and pieces used to fly off to a considerable height. As we stand on the top of the Mountain Limestone and look north from Ingleborough we see in front of us the mouth of the tunnel which carries the Settle and Carlisle Railway through the great mountain mass rising between us and Dent Head. That tunnel was carried through beds of black limestone resting on shale, and with a view to having a hard clean floor the engineers left the bottom thin bed of limestone. But soon I was told that some very curious phenomena were observed in the tunnel. The limestone floor used to bulge and break with loud detonations, and, especially when struck with a pick, pieces used to fly off as high as the roof of the tunnel, to the great danger and alarm of the workmen. What we have in both these cases is what is well known in a coal mine as "a creep," and what in metalliferous mines produces the bursting rock surfaces,* which may give a rational explanation of the mysterious detonations and tappings which are supposed to indicate the presence of productive lodes. If we can observe such movements of strata, happening in the very rocks which we are tracing round Ingleborough, in cases in which artificial operations have hurried up the process, we may surely be on the look out for displacements of the limestones, &c., where we have the whole weight of Ingleborough squeezing out the shales on which they rest.

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* Geol. Mag., Vol. IV., Nov., 1887, p. 511.

THE YOREDALE ROCKS.

None of the sub-divisions of the Yoredale rocks can be continuously traced round Ingleborough, but the presence of limestone is generally indicated by swallow holes above and springs below. The sandstones also, when much jointed and broken, commonly give rise to springs, where the water which has got into the fissured rock is thrown out near the base. The limestones and sandstones generally stand out as terraces and scars, whereas the shales crumble down into steep slopes. The vegetation is, of course, affected by these different conditions, and it is only by observing a great number of small indications that the beds can be traced. The contour lines must not be taken without allowance being made for the amount of drift and talus hanging on the hillside.

To return to the section below Farrer's Shooting Box,* a convenient and easily found starting point, in the bank between the road and the wall, a little higher up stream than the highest bed of marble described on p. 278, there is a mass of dark grey shale (*a* of section, Fig. 4, p. 277). Some of the beds split up with a very smooth flat surface ; others show much conchoidal fracture, which causes small flat pieces with rounded margin to drop out under the hammer. There is generally a rusty stain along the divisional planes, and, as is usual where these ferruginous films occur, fossils are scarce and hard to find. There are numerous small black concretions with rusty exterior and calcareous septa, reminding us of "beetle stones." Some nodules are pierced by tubes which, when broken, look as if they represented borings, but on the outside rather suggest the weathered ends of a very small *Lithostrotion*. I expected *Chonetes hardrensis* in this shale, but I failed to detect it. Perhaps it may yet be found nearer the base where it is passing into the Black Marble, for I take this to be the Hardrow Shale. This fossil occurs abundantly further north, in Linn Gill for instance.

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* Those who wish to wander off the usual routes to the caves or the mountain, in order to carry on their scientific researches, should leave their name and obtain permission from the courteous owner of the property, who deserves the grateful co-operation of our Scientific Societies in his endeavour to protect the indigenous fauna and flora from indiscriminate destruction.

Nothing more is seen until we get up to the Shooting Box, where a spring below and swallow holes above indicate the presence of the Hardrow Limestone at no great depth.

This is suceeded by an even-bedded sandstone in which, some 100 yards to the north, a quarry has been opened to procure stones for walling. About 500 yards further, in Fell Close Sike, a black limestone is exposed, which must be referred to the Hardrow beds, but beyond this its position is a matter of inference from springs and other small indications, until we come to South House Moor Beck, where, about 60 to 65 feet above the highest beds of the Black Marble Series, there are so many fragments of black limestone as to suggest that the Hardrow Limestone is not far off. If it has not thinned out considerably, at any rate it does not make much mark on the ground all round the north end of the hill. A spring here and there, at about the right level, has been taken to mark its lower boundary, and, if it turns round the hill with the other formations west of High Barn, it must be taken below the sandstone by which, whenever the sequence is clearly seen, it is always succeeded in ascending section. Nothing more can be made out clearly about the Hardrow Limestone. The steepness of the hillside and the thickness of the drift plastered on to it have obscured the rest of its outcrop.

The Hardrow Limestone is succeeded in ascending section by a mass of sandstone, sometimes more, sometimes less flaggy and split up by subordinate shales. It cannot be less than 100 feet in thickness and often gives rise to a considerable feature, helping by its prominence and heavy talus to obscure the underlying limestone. It is seen in a quarry about 100 yards north of Farrer's Shooting Box, and again in Fell Close Sike, and is represented by a hard quartzose rock, dipping at a small angle to the north, in a quarry adjoining Fell Close Sike. The flaggy sandstone seen about 300 yards further on, a little west of north, on Fell Close, seems to be a lower part of the same bed. It is seen with limestone resting on it in Shiver Spring, which runs down by Bent Hill Rigg Barn.

About 250 yards west of High Barn, on the boundary line at the north end of the hill, an upper and a lower sandstone are seen, separated by a considerable mass of shale. This series, which may be correlated with the Hardrow Sandstone, is interesting as being the first important arenaceous deposit in the Carboniferous rocks of this area. Though not clearly seen anywhere except in the above-mentioned sections, it can be traced around the remaining part of Ingleborough by the feature to which it generally gives rise and by the underlying and overlying limestones.

The next limestone in ascending order is that which Phillips calls the Simonside Limestone (by later writers written Simonstone). It is well defined along the east and north of Ingleborough, and it may be convenient to begin again in the stream by Farrer's Shooting Box.

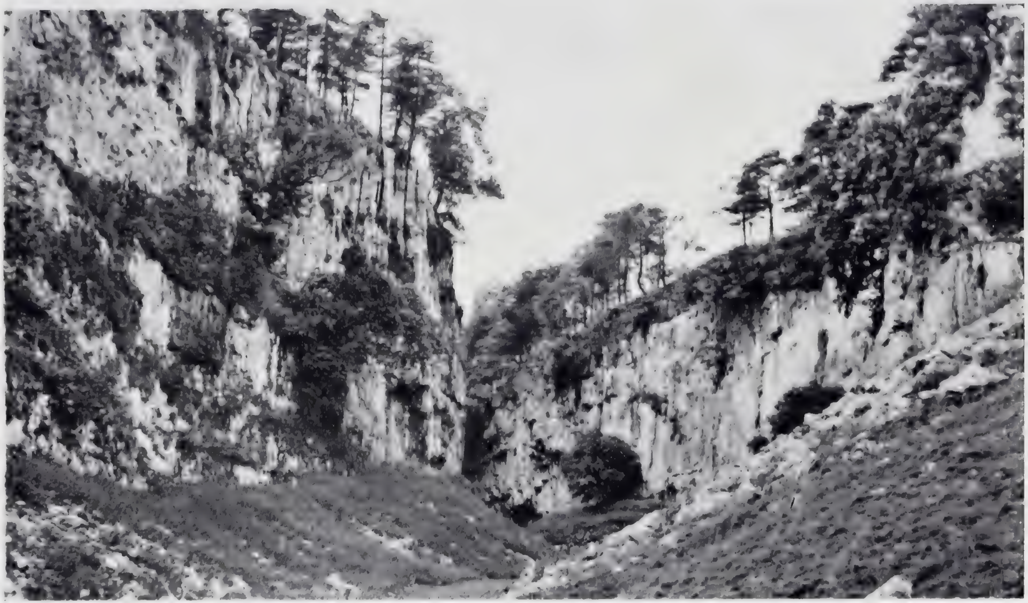
It is seen in the next stream, where there is a swallow hole in it 100 yards north and about the same distance west-north-west of the old Sandstone Quarry. It can be traced by swallow holes about 300 yards to the north, when it is again exposed in Fell Close Sike, beyond which it crops out at frequent intervals all along the breast of the hill, by Borrins Moor to the Sheepfold west of the "Stepping Stone" in South House Moor Beck. It is not exposed again until we reach Old Field Spring, where it is seen with a small dip in a north-north-east direction, about 100 yards north of which it crops out from under a bed of shale on Park Fell. But the clearest section is that exposed in Shiver Spring, where shale is seen resting on 24 feet of limestone, and that on the Hardrow Sandstone. It further crops out at intervals, frequently with shale above it, all round the north end of the hill as far as Keld Bank. It is seen in a swallow hole above the Keld, just below the 1,600 feet contour, and the dark grey crystalline limestone occurring at about the same level in the stream course above Mere Gill must be referred to it. Beyond this it is nowhere seen. Above the Simonside Limestone there is a thick bed of shale with subordinate sandstone. It is exposed in Fell Close Sike, and one of the subordinate sandstones crops out about 300 yards further north. Round the north end of the hill its relation to the limestone above and to that below is clearly seen ; in the stream west-south-west of Bent Hill Rigg Barn, for instance, there is a sandy shale on calcareous sandy shale, on shale with bands of sandstone and concretions, and it is exposed also south-west of High Barn and south of Keld

Bank. It is probably not less than 150 feet in thickness. Above the Fell Close Shale there is another limestone, named by Phillips the Middle Limestone. It occurs under conditions so similar to those affecting the Simonside Limestone that its exposures are almost all exactly above those of the Simonside Limestone and do not call for further indication than this—that if you climb about 150 feet above any section seen in the Simonside Limestone you are almost sure to find a section in the Middle Limestone—a circumstance which would lend peculiar interest to a careful collection of fossils from each.

In the shale above the Middle Limestone a coal occurs further north, at Lunds Thorn, but I have seen no trace of it on Ingleborough.

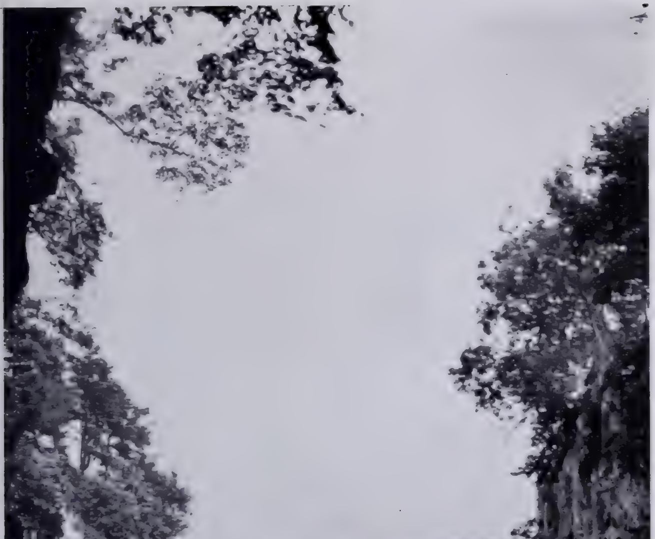
I have indicated the probable occurrence of a thin impersistent bed of limestone about 120 feet below the great sandstone of "Farrer's Allotment" and "Top of South House Moor" (marked on six-inch map). It is nowhere clearly seen, as it occurs in the shale, which has given rise to a gentler slope at the base of the crags, and is therefore covered with drift and peat and heavy masses of tumble from the sandstone above. Its presence is, however, shown by sinkings of the nature of swallow holes in one place and by springs in another.

The shale above, like that below it, contains numerous beds of flaggy sandstones, associated with some of which lines of carbonaceous matter along the north and west flank of Park Fell seem to have suggested the possibility of the occurrence of a coal seam such as is found at this horizon further north. After passing over shales, with an ever increasing slope as we ascend, and hard beds of limestone and sandstone projecting here and there, like the "throughs" in our north country walls, some 500 feet above what we have arbitrarily taken as the base of the Yoredale rocks, we come to a thick mass of sandstone, which gives rise to precipitous crags or very steep slopes covered with rough screes of fallen rock. This is the highest and, indeed, the only very important sandstone of the Yoredale rocks in this district. The rock is of fairly uniform texture, not very coarse, and divided by irregular partings of shale. It is often speckled red, probably from rusted grains of iron pyrites.



THE APPEARANCE OF COLUMNAR STRUCTURE SEEN IN TROW GILL.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXX.

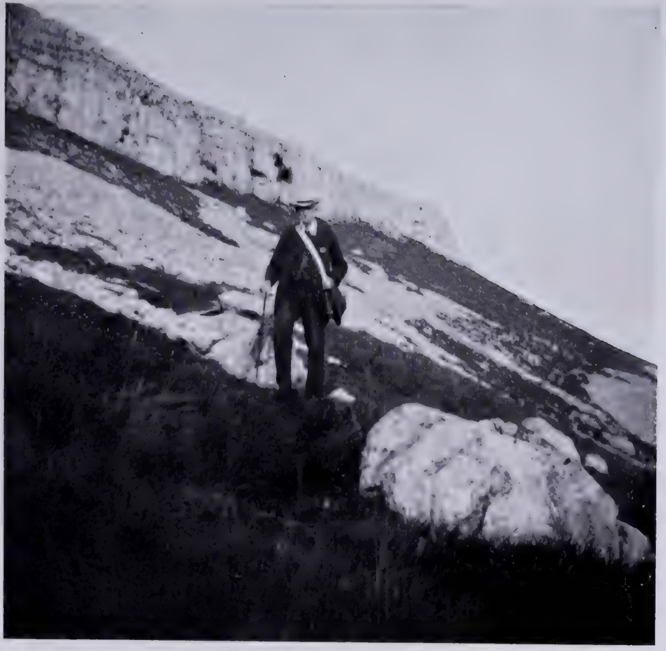


NORBER AND THWAITES SCAR, SEEN FROM TROW GILL.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXI.

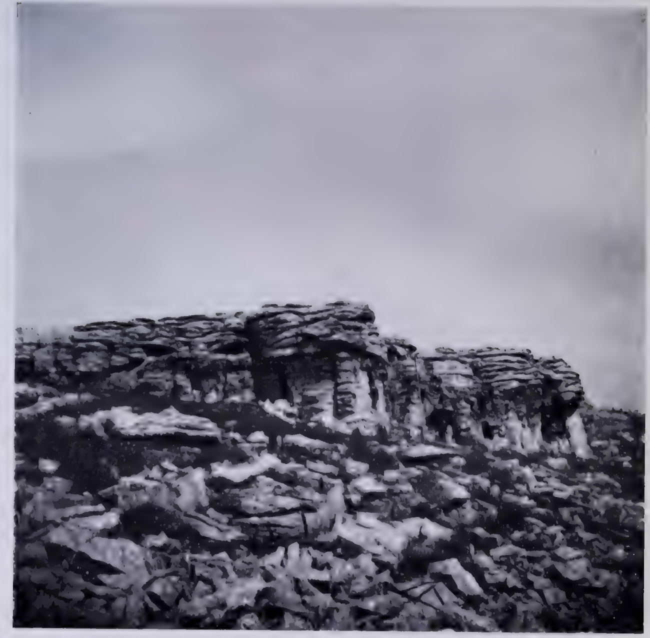
Photographed by Mrs. Hughes. LONG KIN WEST.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXII.



Photographed by Mrs. Hughes. Fig. 1.

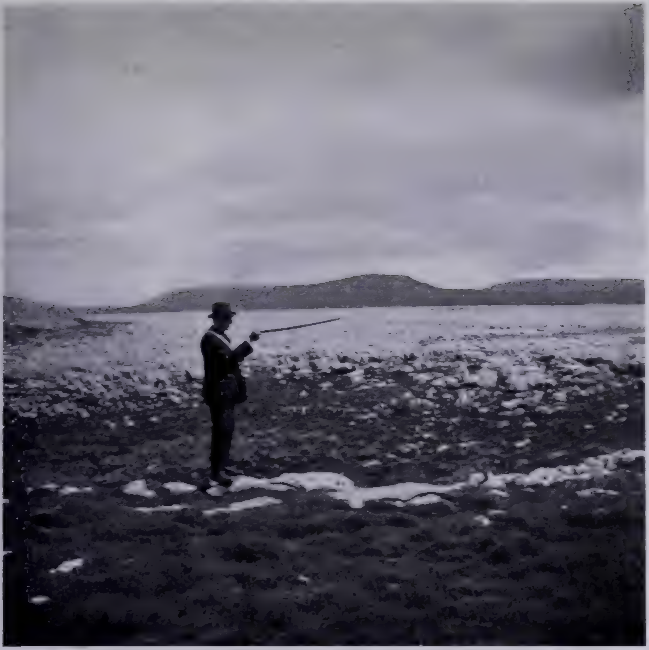
ROBIN PROCTOR'S SCAR, CLAPHAM.



Photographed by Mrs. Hughes. Fig. 2.

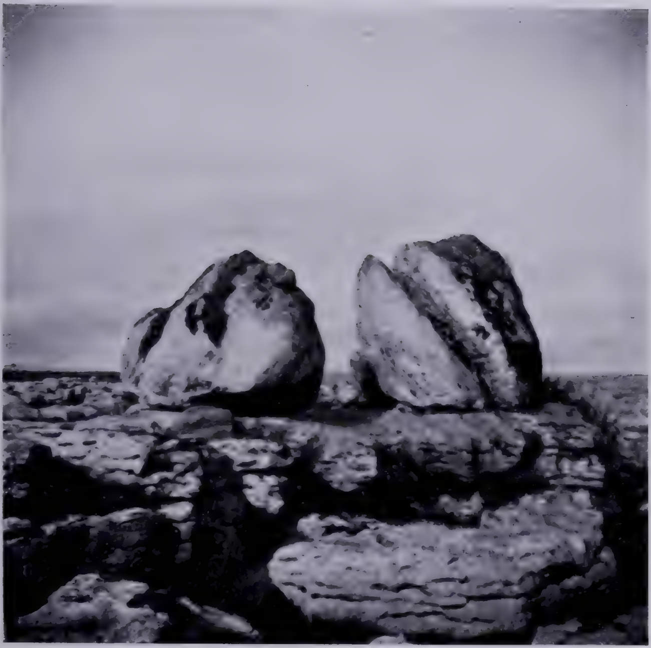
PART OF LONG SCAR, CLAPHAM LANE.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXIII.



Photographed by Mrs. Hughes.

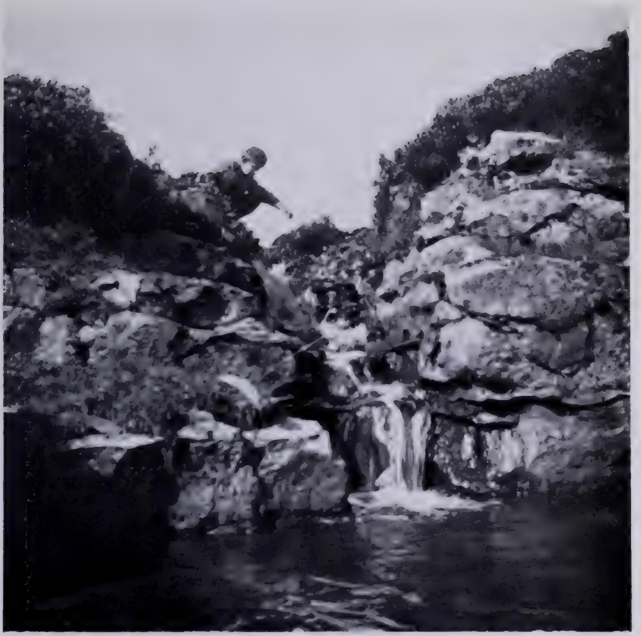
Fig. 1.—LOOKING TOWARD PENYGENT OVER SULBER.



Photographed by Mrs. Hughes.

Fig. 2.—PERCHED BLOCKS OF LIMESTONE ON LIMESTONE.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXIV.



Photographed by Mrs. Hughes.
Fig. 1.

WATERFALL IN BLACK MARBLE SERIES BELOW FARRER'S SHOOTING BOX.

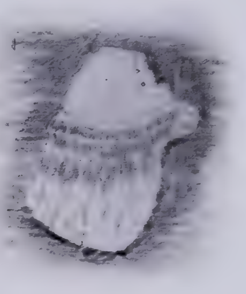


Fig. 2.

FISH FROM BLACK SHALES OF FELL CLOSE SIKE.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXV.

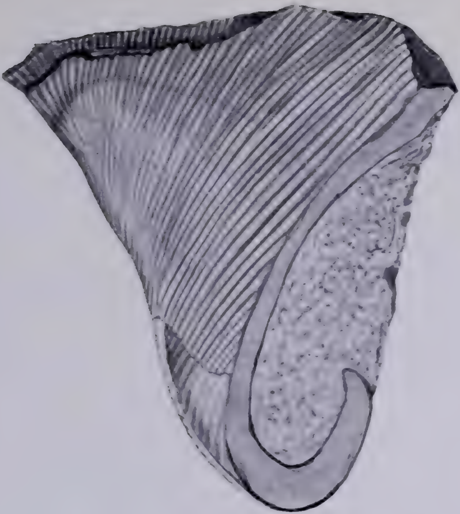


Fig. 1.

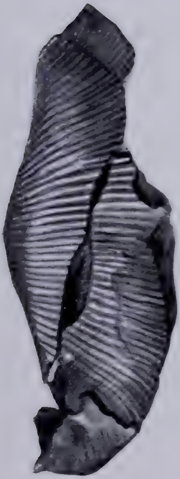


Fig. 2.

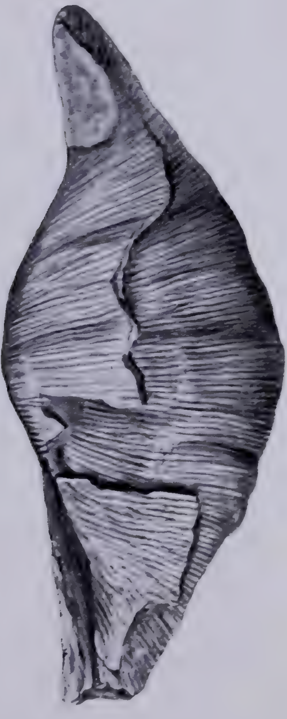


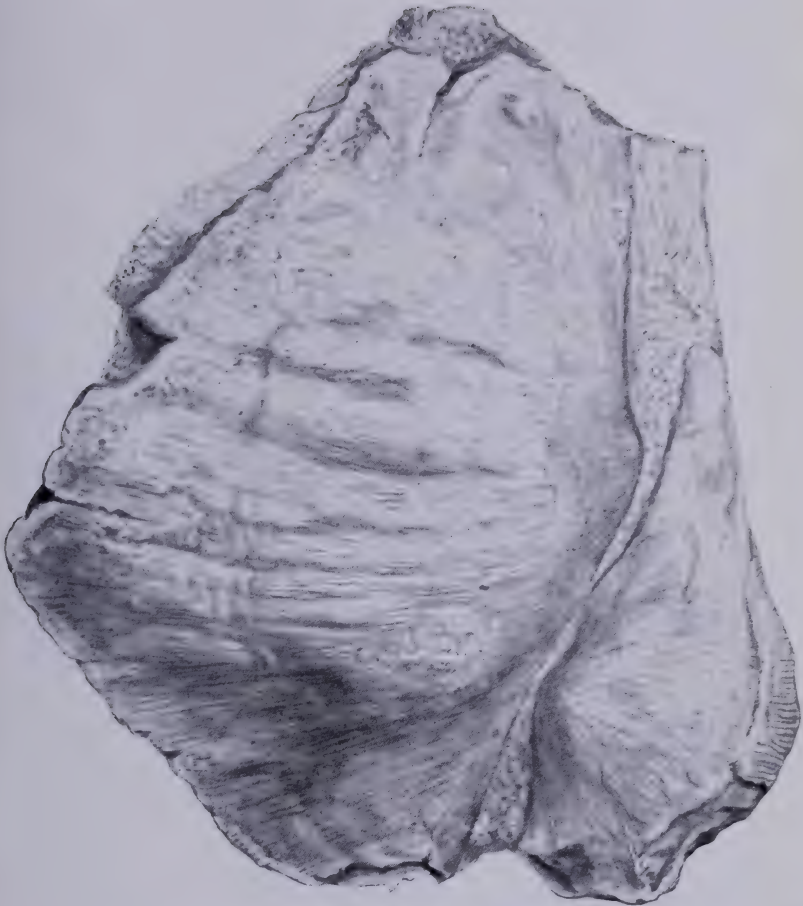
Fig. 3.

Fig. 1.—PRODUCTA LATISSIMA (PHILL.).

Fig. 2.—P. LATISSIMA, YOUNG SPECIMEN.

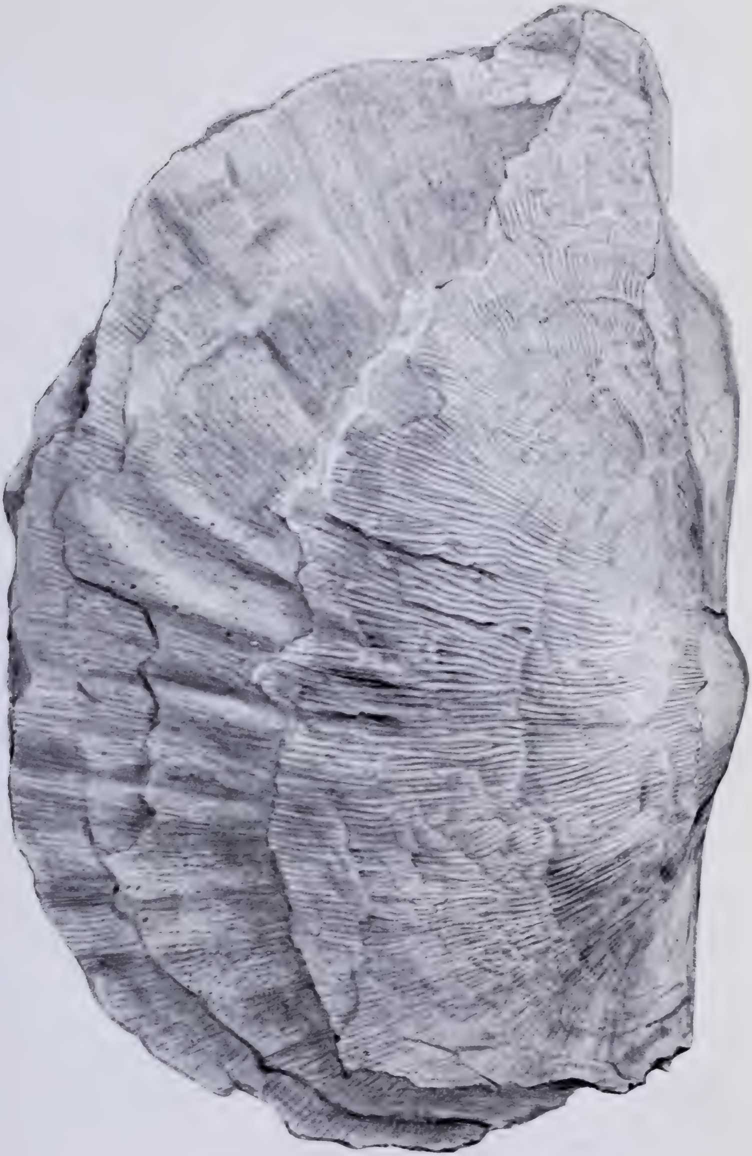
Fig. 3.—P. GIGANTEA, NORMAL TYPE, YOUNG SPECIMEN.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXVI.



PRODUCTA GIGANTEA, NORMAL TYPE, WITH YOUNG SPECIMEN ON THE SAME SLAB.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXVII.



PRODUCTA GIGANTEA, NORMAL TYPE.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXVIII.

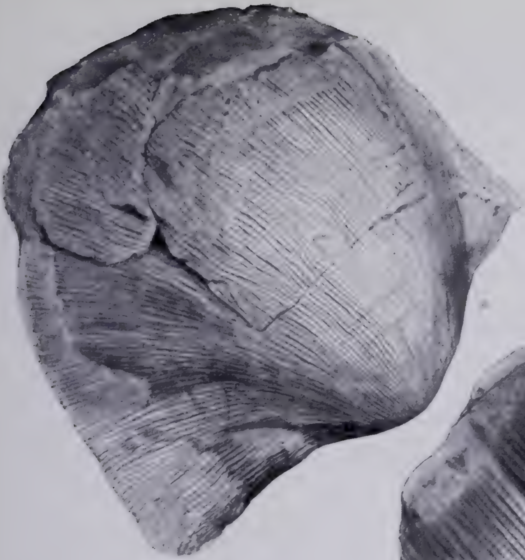


Fig. 1.

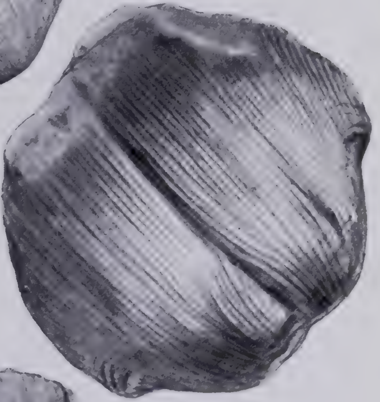


Fig. 3.

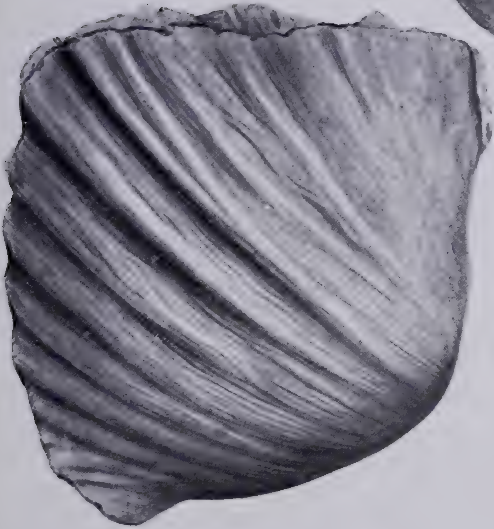


Fig. 2.

Fig. 1.—PRODUCTA GIGANTEA, ROTUND FORM.

Fig. 2.—P. GIGANTEA, ROTUND AND STRONGLY CORRUGATED FORM.

Fig. 3.—P. COSTATA.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XXXIX.

THE MAIN LIMESTONE.

We have now reached the highest limestone seen on Ingleborough, namely the *Upper Scar Limestone* of Sedgwick, and the *Main Limestone* of Phillips, also known as the *Twelve Fathom Limestone.* This occurs on Ingleborough between the 2,100 and the 2,200 feet contours. A small fault, running west-north-west and east-south-east, and passing just south of the cap of grit, throws the limestone down on the south, and shattering the rocks beyond in both directions, though it cannot be clearly traced, may account for the position of some of the swallow holes, such as Tatham Wife Hole, and springs, such as those at Fell Beck Head.

A smaller crack running north and south accounts for the springs on either side of the north-east corner east of Swine Tail.

On the south point of the triangular summit this limestone is well exposed, being seen in numerous swallow holes through the peat and shale on Little Ingleborough, and cropping out in broken and interrupted scars all round the hill. It is not easy to measure the thickness because of the peat and débris which overlap it and the masses of talus which obscure the base, but about 48 feet of it can be seen along the south-east side, while in the north-west precipice, though the top is covered, about 40 feet of limestone may be seen resting on six feet of calcareous sandstone, and that on 10 feet of shaley sandstone which rests on the massive beds of sandstone last described.

The Main Limestone of Ingleborough is separated by about a quarter of a mile of drift and peat from that of Simon Fell, where, owing to the normal dip to the north and east, it is about 100 feet lower. The observed dips, however, do not indicate this, as the rock is somewhat irregular, dipping along the south margin in a southerly direction, and, at the north extremity, falling to the north. This, however, may be due to the breakdown of the rock owing to subterranean denudation of the limestone rather than to original folding. In one case there is, running north-north-west and south-south-east near the north-east margin of this triangular mass of limestone, a line of broken rock which looks very much as if it had broken in over an old cave. The Main or Upper Scar Limestone is an exceedingly interesting deposit. It is the last limestone of any importance in our Carboniferous rocks, for the Crow Limestones of the Millstone Grit are thin and impure and of an entirely different type. It consists of a massive, thick-bedded, grey limestone resting upon the calcareous platy sandstone which passes down into more massive rock. It is full of fossils, especially encrinites, which in the upper part, where the rock is disintegrated, fall apart, so that instead of picking up pieces of encrinital limestone we gather handfuls of encrinite stems. Where the rock does not crumble the fractured surfaces have a coarsely crystalline appearance, largely owing to the calcite of the encrinites breaking along its rhombohedral cleavage and presenting angular projections and clear facets. From the grey crystalline limestone immediately south of the highest point of Ingleborough I have collected the following fossils :—

Thamniscus dubius (King), var. *carbonarius* (Vine).
Spirifera ovalis (Phill.).
S. trigonalis (Mart.).
S. trigonalis (Mart.), var. with smooth medial rib.
Athyris planosulcata.
A. (*Seminula*) *ambigua.*
Rhynchonella [*Hypothyris*] *cordiformis* (Sow.).
Camarophoria crumena (Mart.).
Producta scabricula.
P. spinulosa.
P. semireticulata.
P. pustulosa ?
Leptæna rhomboidalis, var. *analoga.*
Streptorhynchus [*Orthotetes*] *crenistria* (Phill.).
Dielasma sacculus (Mart.).
Capulus neritoides.
Pterinopecten ?

I have on record that *Brachymetopus* has been found here, but this requires verification.

THE "TAURUS RANGE," SETTLE.

There is a mass of limestone on the down-throw side of the great faults to which this portion of the Main Limestone of Ingleborough bears a very strong resemblance, both in lithological character and fossil contents, and could we certainly establish the identity of the two horizons it would be of immense value in the investigation of the age and amount of the great faults and of the character and southward extension of the various sub-divisions of the Carboniferous rocks previous to the occurrence of those faults.

A mile and a half east-south-east of Settle is a beautiful wooded gorge with a waterfall, known as Scaleber Force. On the north of the road north of this there is a ridge of limestone in which quarries have been opened to obtain stone for walling. This limestone is highly fossiliferous, and, fortunately, early attracted the attention of Mr. Burrow, a master in the school at Settle, who made a large collection from it, which is now in the Sedgwick Museum. His specimens are labelled "Carboniferous Limestone, Settle," but the exact locality is not indicated, so that, although the lithological character of the rock has generally enabled us to separate the fossils of the Taurus Range from those found elsewhere in that neighbourhood, there is an unfortunate element of doubt hanging over them. I have, however, a large number collected from this locality by my own excursion parties from Cambridge. On the north of this ridge, jocularly known as the Taurus Range from an episode that occurred on it, there is a hollow broken bit of ground along which there is probably a considerable fault. Beyond this again there is a limestone exposed which differs altogether in appearance and fossil contents from that on the Taurus Range. The more northerly ridge consists of an earthy and occasionally somewhat carbonaceous rock, with *Producta semireticulata*, *Orthis* (*Schizophoria*) *resupinata*, and a great abundance of *Chonetes papillonacea*, reminding us of the beds above the Norber Scars, whereas the limestone of the Taurus Range is highly crystalline, and its crystalline appearance exaggerated by the multitude of broken encrinite stems, of which in places it is almost entirely made up.

We may be prepared to find any part of the Carboniferous rocks let down there, and also to expect slight modifications of lithological character from our knowledge that the conditions of sedimentation were contemporaneously changing south of the Craven Faults, but if the Taurus Limestone is not the Main Limestone it must be part of the Great Scar, in which case we should find a difficulty as to the horizon of the sandstones and shales below Scaleber Bridge. In these shales there are fish remains, and in the Sandstones calcareous nodules and plant remains, such as *Lepidodendron*, *Stigmaria*, and *Calamites*.

COMPARISON OF TOP OF MAIN LIMESTONE AND TOP OF GREAT SCAR.

The top of the Great Scar, it is true, greatly resembles the top of the Main Limestone. In both, grey limestone passes up into a fissile, irregularly-bedded bituminous rock, with finer textured black limestones on top. In both, encrinites are abundant, though at the lower horizon they do not make up the entire mass of the rock. In both, nodular flint and chert occur throughout. The general facies of the fossils is the same in both—masses of *Lithostrotion*, *Syringopora*, and single cup corals occur in both. But the most marked character is the occurrence in the top beds of the irregular bituminous limestone at both the Upper and Lower horizon of very large specimens of the normal form of *Producta gigantea*. The upper part of the grey encrinital limestone of the Upper Scar becomes darker, more bituminous, and shaley in places, and in these uppermost beds large specimens of the normal type of *Producta gigantea* occur abundantly. They are seen *in situ* along the south side of the wall that bounds the north-east brow of Simon Fell north of Lord's Seat, but better specimens can be procured from the adjoining walls. So exactly do these fossils resemble the specimens obtained from the top beds of the Great Scar below, that one very distinguished palæontologist, who had not seen them *in situ*, suggested that they must have been brought up from the lower horizon for walling, having no doubt that the species were identical. In the earlier stages of growth the shell generally expands chiefly along the hinge line, so that it is cigar-shaped, but later on it ceases to extend so rapidly in the direction of its breadth, but develops the great wavy curtain-like shell which is so characteristic of the species. The figure on Plate XXXVII. shows an adult form and a young specimen on the same piece from the top of the Upper Scar Limestone on Simon Fell. The figure on Plate XXXVIII. represents a full grown specimen from the top of the Great Scar Limestone at Hull Pot—and a young specimen from the same locality is given on Plate XXXVI., Fig. 3. Sometimes the shell is developed earlier in the direction of its length, and in that case a more rotund form is produced, as, for example, that shown on Plate XXXIX., Fig. 1.

The specimens found at both of these horizons show great variation in the amount of corrugation of the shell. To keep up the figure, in some the curtain is more pulled out and in others more squeezed up into plaits, and the folds are in some very irregular, while in others they are stronger and more symmetrical, as in the specimen figured Plate XXXIX., Fig. 2.

In the Black Marble, above the black limestones which form the top of the Great Scar, there is another form, which in its younger stages may be confounded with the younger forms of *P. gigantea*. This is the *P. latissima* of Phillips (see Plate XXXVI., Figs. 1 and 2). Where only a fragment of the shell is seen, especially when that happens to be a more rotund form, it may be mistaken for a variety of *P. costata* (see Plate XXXIX., Fig. 3), from the even ribbing and obscure spine scars, but in good specimens the difference of form and the corrugations on the wings of *P. costata* enable us to distinguish them easily.

The examination of a large number of examples generally enables us to arrive at a pretty satisfactory conclusion as to their affinities, but we want scores, perhaps hundreds, of specimens to test the range of individual variation, which in the case of the species we are considering is very great, and these difficulties explain and justify the remarks on pp. 254-256 as to the work among the fossils of Ingleborough that offers itself to the student.

There is at the present time a "boom" on *zoning*, and excellent work has been done upon it, but the value of the results depends upon how nearly the observers have exhausted the evidence. To assert that any form "a" does not occur at the same horizon as another form "d" is only to say that the observer has not yet found it there; and, when we remember that, in the sections of which I am speaking, very few could find the Lower Zone of even such a large conspicuous fossil as *P. gigantea* in the stream below the Shooting Box, and that, if the weather is bad, not even one who knows every inch of the ground could be sure of showing you that species *in situ* in the Upper Zone on Simon Fell, we may well be cautious about basing important generalisations on negative evidence.

The next stage will be a "boom" on *unzoning*, that is upon proving the greater continuity of life than has been supposed in certain areas, with remigrations into adjoining areas as conditions again become suitable for any particular species, unless in the interval that species has become extinct. Palæontologists are much inclined to exaggerate the importance of individual variations, especially when looking over collections made for them, and they have not themselves had opportunities of studying the variations on the field, and the variation has not been uniformly impressed upon a sufficiently large number of individuals to constitute what is technically known as a *variety*.

The Top of Ingleborough.

The Main Limestone is succeeded by shale, which is nowhere seen in a clear section where its thickness could be exactly measured or its character observed. It is probably over 120 feet in thickness and seems, from fragments lying about, to contain some bands of flaggy sandstone. It is seen resting on the limestone at the Arks on the north side of the summit, and crops out a short way below the sandstone on the south side. Fragments of shale occur also in a similar position below the northwest corner. A small excavation would clear up these points and give an opportunity of looking for fossils in the calcareous platy beds on top of the Main Limestone. Swallow holes occur here and there above the outcrop of the Main Limestone, sometimes higher than we should expect them, because of the great mass of talus that has crumbled down upon it. The shale between the Millstone Grit and the Main Limestone is exposed in a swallow hole at the south end of the hill.

The top of Ingleborough is not quite level, but rises slightly to the north-west, swelling up a little about the centre. This is partly due to a slight dip to the south-east and also to the manner of denudation of the softer strata which occur on the summit.

The highest beds seen consist of flaggy grit and sandstone, but there is no clear section through them, the surface being everywhere covered with a mass of angular débris, apparently derived from the underlying rocks. I once dug through this to the depth of between three and four feet and found what appeared to be the disintegrated surface of the rock in place. It was not only broken up along joints into angular fragments, but often decomposed into a coarse sand. In the finer beds I have found two species of lamellibranch, *Anthracosia* sp. and *Sanguinolites plicatus* (Portl.), and in the coarser beds fragments of *Calamites* and *Stigmaria*. These flags rest upon a coarse grit full of pebbles of white quartz, about the size and form of horse beans and marbles. There are occasionally small flat pieces of ironstone to three inches in diameter in the grit, but it is not clear whether they are concretionary or rolled fragments. The coarse grit passes down into a finer grained rock with no pebbles, but false bedded sandstones and grit are apt to change within very short distances, a very good example of which may be seen in the sandstone of the Yoredale Series just below, where one of the beds of sandstone is chamfered off by cross current action, so that the end of a ten foot bed stands at about the steepest slope that sand would rest at under water. It is thus a question where we should draw the base of the Millstone Grit, but in a continuous series like this it is an arbitrary division and of little importance, and it is most improbable that we can establish an exactly synchronous base throughout the district ; all we can hope for is the selection of the "geological equivalent"* or what was afterwards called the "homotaxeous deposit,"† which is most convenient for each locality.

It is about 70 feet from the base of the grit on the south side to the top of the hill, and, allowing something for the general rise of the beds to the north-west, we may estimate the thickness of the pebbly grit at about 33 feet and the flaggy grit at about 30 feet more.

In one place on the west side the coarse grit rests on a fine sandstone, which, as may be inferred from the fragments seen below, passes down into sandy shale.

It is obvious that enormous masses of the cliff round the top of the hill have crumbled down or slipped bodily on to the ledge formed by the Main Limestone. The grit is traversed by great open joints, the water in which freezes and shatters the rock, while the shale at the top of the Main Limestone facilitates slips. The fractured rocks so often seen in such situations after thunderstorms suggest that lightning may have materially helped the work of destruction at these high elevations. Considerable slips are seen along the east side, especially at the south-east corner, where a small fault has probably helped to determine their mode of occurrence. The fallen blocks are often from six to ten feet in length, but it is difficult to explain the position of the heaps of broken rock that occur near the top. Some may have been pushed forward by ice, and represent a stage in its recession, as, for instance, the boulders known as the "White Stones." All along the east and south-east outcrop of the Main Limestone the beds are turned over as if under the influence of a forward thrust, and many large masses lie far beyond where we should naturally expect to find them. On the north side especially the talus presents a grand scene of desolation, like the ruin of some cyclopean wall. In some cases the main mass of this rampart of fallen rock stands off from the base of the cliff, forming a sort of lunette in advance of it. This may be due to the blocks having slid down over a slope of snow which lies long in the shelter of these northern precipices, and would linger there through the season of early thaw, and, consequently, of the chief falls of rock (see Fig. 9). The result of the summer's weathering also is seen in a talus close to the foot of the cliff.

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* Whewell, History of the Inductive Sciences, 1837, Vol. III., p. 532.

† Huxley, Q.J.G.S., Vol. XVIII., 1862, p. xlii., Vol. XXVI., 1870, p. xlii.

The height of Ingleborough is 2,373 feet above Ordnance Datum. Simon Fell is a little over 2,100 feet. Near the line of the section the base of the Mountain Limestone on the Ingleton-Weathercote road is at the 800 feet contour, and, taking the shortest line to the top of Ingleborough, we cross the top of the Great Scar, including the Black Shaley Limestone and the Black Marble, on the 1,400 feet contour, giving a thickness of 600 feet for the Great Scar. We reach the top of the Yoredale rocks on the 2,250 line, which gives 850 feet for the Yoredale rocks, leaving 123 feet for the Millstone Grit, including the flaggy beds above the coarse grit and the sandstone at its base.

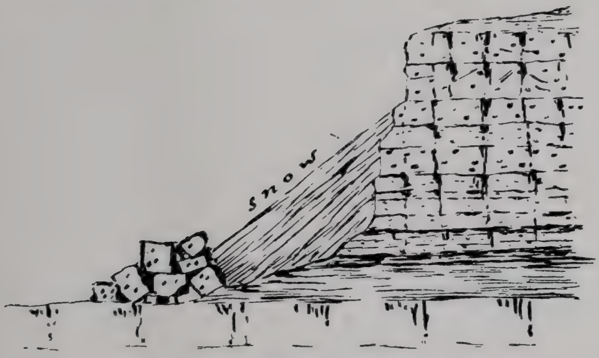

Fig. 9.

The principal source of error in this estimate is in the fact that the base of the Carboniferous rocks is falling fast to the north across the line of our section, so that a slight shift in its direction would give somewhat different results, and perhaps these measurements give too low a figure for the thickness of the Great Scar Limestone and of the Yoredale rocks, but they furnish a fair approximation which can be easily checked by similar traverses up other sides of the mountain.

As we stand on the top of the highest Carboniferous beds of Ingleborough, we may ask how much is gone from above, and how much that represents what once extended over Ingleborough has been thrown down and lies under the drift-covered country below us as we look out seaward ?

When we are speculating upon the age of the earth movements of which we have direct evidence in this district, we must bear in mind the Basement Beds containing corals, which appear to have been broken and overthrown and shifted from their original place, with the great stones to which they had been attached, while close by we find them still undisturbed in the position in which they grew. Now these corals are not things that sprung up like mushrooms in a night ; they are large masses of slow growth by budding, and the manner in which they now occur is quite consistent with the view that there were recurrences of changes of current and disturbances of sediment, such as might be supposed to accompany earth movements.

Here and there throughout the limestones, beds are found made up of angular fragments, which are not due to brecciation in place, and yet cannot have been far transported, while the broken corals and other fossils which occur in them suggest the breaking up of recently formed deposits. An interesting paper bearing upon this question has recently appeared in the Bulletin of the Soc. Belge de Géologie.*

No such thing is known, or probable, as that there should be an uplift of 5,000 feet or so *à un seul jet*, as Elie de Beaumont would have said ; and, if the relative displacement was gradual, that must have affected the character of the formations on the north and south side of the Craven Faults, which were the axis of the movement. Did that movement commence in Carboniferous times, and through what geological ages did it extend ? Here surely is question of *la haute géologie* worthy of a place in your programme of work.

Let us now turn round and look inland. We see gently rounded hills moulded out of the old Sea Plain. Sometimes, as in the case of Ingleborough and Penygent, they are smoothed on the north and more abrupt on the south, like the "crag and tail" of Scotch geologists. On either side of us we have hanging valleys, as in Chapel-le-Dale, Kingsdale, Crummack, and Ribblesdale, abruptly cut off and emptying their waters by gorge and cascade into the lower and larger straths below. Everywhere we come upon glaciated surfaces, perched blocks, and scratched stones, which run up to 1,800 feet on the hills to the north, and up to 1,400 feet on Ingleborough itself, but none of them far transported. In all these we see plainly written on the rocks the history of an episode during which this district presented the appearance of the marginal regions of Greenland. Shall we venture to connect these two subjects of speculation, and ask whether if such an upheaval as we believe did take place once upon a time were to have recurred in recent ages, and Ingleborough and Penygent were between 7,000 and 8,000 feet or more in height, glaciers would not again creep down their sides? Anyone who has seen, as I have, masses of snow many feet in thickness lying in Long Kin West on the 4th of July, can easily believe that a much smaller uplift than that would cover these heights with perpetual snow. The precipices of Ingleborough have crumbled down all round—some more, some less. The north end of the hill presents a grand scene of ruin, and yet this was the part that must have been swept most clean by the great mass of ice that once advanced from the gathering ground on the north, and split on the end of Ingleborough. If this be so, this breaking up of the rocks must have taken place after the ice had left it. The top of Ingleborough must have stood far above the glaciers that continued to creep down Ribblesdale and Chapel-le-Dale in later glacial times, and it is to the various successive stages of a continuous diminution of ice, with its accompanying moraines and glacier streams, that we must refer many of its most striking superficial phenomena. While glaciers were grinding along the bottom of the hill, what was practically post-glacial denudation was going on near the top, where frost and sunshine and rain and lightning have been at work ever since.

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* Sur l'Origine de la Grande Brèche Viséenne et sa Signification Technique, par H. de Dorlodot. Bull. Soc. Belge de Géol. Vol. XXII. (1908) p. 29.

DESCRIPTION OF PLATES.

XXIX.	Map and section of Ingleborough.
XXX.	The appearance of columnar structure seen in Trowgill. From a photograph.
XXXI.	Norber and Thwaites Scar, seen from Trowgill. From a photograph.
XXXII.	Long Kin West, Ingleborough. From a photograph by Mrs. Hughes.
XXXIII	Fig. 1.—Robin Proctor's Scar, showing a long slope of talus below a scar which is still being cut back. The fossils mentioned on p. 275 were found on the extreme right of the spectator. From a photograph by Mrs. Hughes. Fig. 2.—Scar in which horizontal divisional planes due to bedding are seen above the vertical planes due to jointing, Long Scar. From a photograph by Mrs. Hughes.
XXXIV.	Fig. 1.—Clints west of Sulber. From a photograph by Mrs. Hughes. Fig. 2.—Blocks of Mountain Limestone transported by ice from a lower horizon further north. From a photograph by Mrs. Hughes.
XXXV.	Fig. 1.—Waterfall in Black Marble Series below Farrer's Shooting Box. From a photograph by Mrs. Hughes. Fig. 2.—Fish from black shales of Fell Close Sike.
XXXVI.	Fig. 1.—*Producta latissima* (Phill.) from the Black Marble Series, Farrer's Shooting Box, Ingleborough. Fig. 2.—Young of *P. latissima* from same locality. Fig. 3.—Young of *P. gigantea*, normal type (see plate XXXVIII.)
XXXVII.	*P. gigantea*, normal type, with young specimen on the same slab, from the Main or Upper Scar Limestone, Simon Fell, Ingleborough.
XXXVIII.	*P. gigantea*, normal type (see also young specimen from the same horizon and locality, Plate XXXVI., Fig. 2), from the black limestone on the top of the Great Scar or Mountain Limestone, Hull Pot, Horton-in-Ribblesdale.

XXXIX. Fig. 1.—*P. gigantea*, rotund form, from the Lower Gigantea Zone, below Farrer's Shooting Box, Ingleborough.

Fig. 2.—*P. gigantea*, rotund and strongly corrugated form, from the top of the Mountain Limestone, Plovrigg, Crosby Ravensworth.

Fig. 3.—*P. costata*, from the Lower Gigantea Zone, Hull Pot, Horton-in-Ribblesdale.

DESCRIPTION OF MAP, PLATE XXIX.

The map is drawn on the scale of nearly 2,000 feet to the inch, and is intended to show the outcrops of the Grit on the summit; of the Massive Sandstone under the Main Limestone; and all the limestones of the Yoredale Series down to the Great Scar or Mountain Limestone.

The principal streams and other features referred to in the paper are shown.

The line of section across Simon Fell, on the same scale as the map, is indicated by a dotted line.

The letter A refers to the Black Shaley Limestone (the Lower Zone of *Producta gigantea*) on top of the Great Scar or Mountain Limestone.

B is the Black Marble above and separated by a shale from the Lower Gigantea Zone. No line is drawn between A and B and the dividing shale is not shown on the map.

C is the Hardrow Limestone.

D the Simonside Limestone.

E the Middle Limestone.

F the "Impure Productal Limestone."

G the Main or Upper Scar Limestone, including the Upper Gigantea Zone.

APPENDIX.

Mr. Burrow collected chiefly from the "Taurus Range," and referred what he found to the best authority available on each group.

Since the collection has been in the Sedgwick Museum (known as the Woodwardian Museum when it was presented), Mr. F. Cowper Reed has been carefully over it, and therefore it is of exceptional value, notwithstanding the doubt that exists respecting the exact spot in the neighbourhood of Settle where each specimen was obtained.

We have been able to verify the locality in a large number of instances from the collections made during my excursions in that district, on which I was frequently accompanied by good palæontologists, such as M. Lohest, Tom Roberts, and many another now well known to fame. The list, therefore, may be useful and I publish it in an appendix.

To Mr. Reed I am further indebted for the revision of all my lists.

FOSSILS FROM THE CARBONIFEROUS LIMESTONE, SETTLE.

BURROW COLLECTION.

SPONGIA.
- *Hyalostelia* sp.

ACTINOZOA.
- *Amplexus coralloides* (Sow.).
- *A.* sp.
- *Axophyllum ?*
- *Campophyllum Murchisoni* (Milne Edw.).
- *Calamopora* [*Chætetes*] *tumida* (Phill.).
- *Cladochonus* (*Monilipora*) *crassus* (McCoy).
- *Clisiophyllum bipartitum* (McCoy).
- *C.* sp.
- *Cyathaxonia cornu* (Mich.).
- *C.* sp.
- *Cyathophyllum Murchisoni* (M. Edw.).
- *C. paracida ?* (McCoy).
- *C. Stutchburyi* (M. Edw.).
- *C.* sp.

Turbinolia [*Cyclophyllum*] *fungites* (Flem.).
Calamopora [*Favosites*] *parasitica* (Phill.).
Fistulipora ?
Lithostrotion affine (Flem.).
L. basaltiforme (C. & Ph.).
L. irregulare (Phill.).
L. junceum (Flem.).
L. mcCoyanum (M. Edw.).
L. Martini (M. Edw.).
Michelinia megastoma (Phill.).
Monticulipora ? (*Calamopora ?*).
Syringopora geniculata (Phill.).
S. ramulosa (Goldf.).
Zaphrentis cylindrica (Scouler).
Z. Enniskilleni (M. Edw.).
Z. Griffithi (M. Edw.).
Z. Phillipsi (M. Edw.).
Z. sp.

ECHINODERMATA.

Actinocrinus costus (McCoy).
Amphoracrinus amphora (Gilb.), var. *Gilbertsoni* (Phill.).
Archœocidaris sp.
Astrocrinus Benniei (Eth.).
Codonaster (*Codaster*) *trilobatus* (McCoy), var. *acutus* McCoy.
Cyathocrinus ? in shale.
Pentremites [*Granatocrinus*] *ellipticus* (Sow.).
P. [*G.*] *orbicularis* (Sow.).
Lageniocrinus ?
Pentremites ?
Platycrinus granulatus (Miller) in shale.
Poteriocrinus.
Synbathocrinus conicus (Phill.) ?

POLYZOA.

Ceriopora irregularis (de Kon.).
Fenestella membranacea (Phill.).
F. plebeia (McCoy).

F. polyporata (Phill.).
F. nodulosa (Phill.).
Retepora [*Glauconome*] *pluma* (Phill.).
G. pulcherrima (McCoy).
G. sp.
Palæocoryne.
Polypora multiporata (McCoy).
P. papillata (McCoy).
P. sp.
Ptylopora sp.
Millepora [*Pustulopora*] *oculata* Phill.
M. [*Rhabdomeson*] *interporosum* (Phill.).
M. [*R.*] *rhombiferum* (Phill.).
Rhombopora dichotoma (McCoy).
R. megastoma (McCoy).
Flustra [*Sulcoretepora*] *parallela* (Phill.).

CRUSTACEA.

Brachymetopus ouralicus (de Vern).
Cyclus bilobatus (H. Woodw.).
C. Harknessi (H. Woodw.).
C. radialis (H. Woodw.).
C. Woodwardi (Reed).
C. sp.
Cyprella chyrsalidea (de Kon.).
Cypridella edwardiana (de Kon.).
Cypridellina Burrovi (I. K. & B.).
Cypridina cruciata (de Kon.).
C. primœva McCoy.
C. primæva var.
C. sp.
Cythere (*Leperditia*) *inflata* McCoy.
Dithyrocaris Scouleri (McCoy).
Entomis biconcentrica (R. Jones).
Entomoconchus Scouleri (McCoy).
E. sp.
Griffithides acanthiceps (H. Woodw.).
G. globiceps (Portl.).

G. longiceps (Portl.).
G. moriceps (H. Woodw.).
G. seminiferus (H. Woodw.).
G. sp.
Phillipsia Bronginarti (Fischer).
P. carinata (Salt, M.S.).
P. derbiensis (Martin).
P. Eichwaldi (Fischer), var. *mucronata* McCoy
Asaphus [*P.*] *gemmulifera* (Phill.).
A. [*P.*] *truncatula* Phill.

BRACHIOPODA.

Athyris (s.g. *Seminula*) *ambigua* Sow.
Athyris expansa (Phill.).
A. globularis (Phill.).
A. squamosa (Phill.).
A. (*Actinoconchus*) *planosulcata* (Phill.).
A. (s.g. *Cliothyris*) *Roysii* (L'Ev.).
A. (s.g. *Seminula*) sp.
Camarophoria crumena (Mart.).
C. rhomboidea (Phill.).
C. seminula (Phill.).
Chonetes buchiana (de Kon.) in shale.
C. dalmaniana (de Kon.).
C. hardrensis (Phill.).
C. laguessiana (de Kon.).
Spirifera [*C.*] *papilionacea* (Phill.).
C. polita (McCoy) in shale.
C. sp.
Crania quadrata (McCoy).
Spirifera [*Cyrtina*] *septosa* (Phill.).
Discina [*Orbiculoidea*] *nitida* (Phill.).
Retzia [*Hustedia*] *intermedia* (de Kon.).
Terebratula [*H.*] *radialis* (Phill.).
Orthis keyserlingiana (de Kon.).
O. (*Rhipidomella*) *Michelini* (L'Ev.)
O. (*Schizophoria*) *resupinata* (Mart.).
O. (*S.*) Scaleber, Settle.

O. (*S.*) var. *gibbera* Portl.
O. sp.
Producta aculeata (Mart.).
P. cora (d'Orb.).
P. costata (Sow.).
P. deshayesiana (de Kon.).
P. erminea (de Kon.).
P. fimbriata (Sow.), also from Scaleber.
P. gigantea (Sow.).
P. gigantea var. *hemisphærica.*
P. keyserlingiana (de Kon.).
P. köninckiana (de Vern.).
P. longispina (Sow.).
P. longispina var. *lobata.*
P. margaritacea (Phill.).
P. marginalis (de Kon.).
P. mesoloba (Phill.), also Scaleber.
P. nystiana ? (de Kon.).
P. plicatilis (Sow.).
P. (*Proboscidella*) *proboscidea* (de Vern.).
P. punctata (Mart.).
P. pustulosa (Phill.), also Scaleber.
P. scabricula (Mart.), also Scaleber.
P. semireticulata (Mart.).
P. semireticulata var. *Martini* (Sow.).
P. spinulosa (Sow.).
P. striata (Fischer).
P. tessellata ? (de Kon.).
P. undata (Defrance).
P. undifera (de Kon.).
P. youngiana (Dav.).
P. sp.
Rhynchonella [*Hypothyris,* s.g. *Pugnax*] *acuminata* (Mart.).
R. [*H.,* s.g. *P.*] *pugnus* (Mart.).
R. [*Rhynchotreta ?*] *angulata* (Linn.).
R. [*Hypothyris,* s.g. *Pugnax*] *cordiformis* (Sow.).
R. [*H.,* s.g. *P.*] *pulchella* (de Kon.).

R. [*Hypothyris*] *multirugata* (de Kon.).
[*H.*] *pleurodon* (Phill.), also Scaleber.
Rhynchonella ? trilatera (de Kon.).
R. [*Hypothyris præcox* (de Kon.) ?
R. [*Hypothyris*, s.g. *Pugnax*] *brockleyensis* (Dav.).
R. [*H.*, s.g. *P.*] *triplex* (de Kon.).
R. [*H.*, s.g. *P.*] *McCoyi* (de Kon.) ?
R. [*H.*, s.g. *P.*] sp.
R. [*H.*, s.g. *P.*] cf. *lacta* (de Kon.).
Spirifera duplicosta (Phill.).
Sp. (*Martinia*) *glabra* (Mart.).
Sp. integricostata (Phill.).
Sp. lineata (Mart.).
Sp. lineata var. *imbricaca* (Sow.).
Sp. lineata var. *elliptica* (Phill.).
Sp. ovalis (Phill.).
Sp. pinguis (Sow.).
Sp. pinguis var.
Sp. striata (Mart.).
Sp. triangularis (Mart.).
Sp. trigonalis (Mart.) (= pars *S. bisulcata* (Sow.)).
Sp. trigonalis var. *bisulcata* (Sow.) (= pars *S. bisulcata* (Sow.)).
Sp. crassa (de Kon.).
Sp grandicostata (McCoy).
Sp. triradialis (Phill.).
Sp. Urii (Flem.).
Sp. cf. *spissa* (de Kon.).
Sp. subcincta (de Kon.).
Spiriferina octoplicata (Sow.).
S. acuticostata (de Kon.).
Spirifera [*S.*] *insculpta* (Phill.) ?
Sp. [*Streptorhynchus* [*Orthotetes*] *crenistria* (Phill.).
Sp. [*Derbya*] *senilis* (Phill.).
Strophomena [*Leptæna*] *rhomboidalis* (Wilckens).
S. [*L.*] *rhomboidalis* var. *analoga* Phill.
Spirifera [*Syringothyris*] *cuspidata* (Mart.).
Terebratula [*Dielasma*] *normalis* (de Kon).

[*D.*] *sacculus* (Mart.) and vars.
[*D.*] *vesicularis* (de Kon.).
[*D.*] *gillingensis* (Dav.).
[*D.*] *attenuatum* (Mart.).
[*D.*] cf. *antiqua* (de Kon.).
[*D.*] *avellana* (de Kon.).
[*D.*] cf. *amygdaloides* (de Kon.).
[*D.*] *lenticularis* (de Kon.).
[*D.*] *radiata* (de Kon.).
[*D.*] *intermedia* (de Kon.).
[*D.*] (*Cryptonella ?*) *reflexa* (de Kon.).

LAMELLIBRANCHIATA.

Arca [*Parallelodon*] *fallax* (de Kon.).
A. [*P.*] *theciformis* (de Kon.).
A. [*P.*] *Walciodorensis* (de Kon.).
A. [*P.*] *squamosa* (de Kon.).
A. [*P.*] *corrugator* (de Kon.).
A. [*P.*] *cancellata* (Mart.).
Byssoarca [*P.*] *reticulata* (McCoy).
Modiola [*P.*] *squamifera* (Phill.).
Pullastra [*P.*] *bistriata* (Portl.).
Pterinea [*Leiopteria*] *Thompsoni* (Portl.).
Gervillia [*L.*] *lunulata* (Phill.).
P. [*Aviculopecten*] *disimilis* (Flem.).
P. [*A.*] *plicatus* (Sow.).
P. [*A.*] *clathratus* (McCoy).
P. [*A.*] *nobilis* (de Kon.).
P. [*A.*] *semicostatus* (Portl.) ?
P. [*A.*] *stellaris* (Phill.).
P. [*A.*] *interstitialis* (Phill.).
P. [*A.*] *tabulatus* (McCoy).
P. [*A.*] *Murchisoni* (McCoy).
P. [*A.*] *incrassatus* (McCoy).
P. [*Crenipecten*] *semicircularis* (McCoy).
P. [*Pseudamusium*] *anisotus* (Phill.).
P. [*Limatulina*] *desquamatus* (McCoy).
P. [*Pterinopecten*] *dumontianus* (de Kon.).

P. [*P.*] *bosquetianus* (de Kon.).
P. [*P.*] *granosus* (Sow.).
P. [*Eumicrotis*] *hemisphæricus* (Phill.).
P. [*Palæolima*] *simplex* (Phill.).
Lima [*Aviculopecten*] *decussata* (McCoy).
Dolabra [*Protoschizodus*] *rectangularis* (McCoy).
Cardiomorpha orbicularis (McCoy).
Concardium aliforme (Sow.), also Scaleber, Settle.
C. rostratum (Mart.).
C. alatum (de Kon.).
Pleurorhynchus [*C.*] *inflatum* (McCoy).
Cardium [*C.*] *irregulare* (de Kon.).
Cypricardia [*Mytilomorpha*] *rhombea* (Phill.).
Sanguinolites [*Cypricardella*] *annæ* (de Ryckholt).
Entolium [*Amusium*] *tenue* (de Kon.).
Avicula [*Pseudamusium*] *sublobata* (Phill.).
A. [*Pterinopecten*] *tessellata* (Phill.).
A. [*P.*] *radiata* (Phill.).
Pterinea [*Aviculopecten*] *intermedius* (McCoy).
Rutotia [*Eumicrotis*] *ovalis* (de Kon.).
Lima [*Limatulina*] *alternata* (McCoy).
Broeckia mutica (de Kon.).
Hiatella [*Allorisma*] *sulcata* Flem.
Sanguinolaria [*Edmondia*] *oblonga* (Portl.).
E. McCoyi (Hind).
Lucina [*E.*] *laminata* (Phill.).
Modiola [*Lithodomus*] *lingualis* Phill.
M. [*Posidoniella*] *elongata* (Phill.).
Myalina lamellosa (de Kon.).
M. peralata (de Kon.).
Avicula [*M.*] *Verneuilli* (McCoy).
Inoceramus [*Posidoniella*] *vetustus* (Sow.).
Posidoniella pyriformis (Hind).
Pinna flabelliformis (Mart.).
P. mutica (McCoy).
Cypricardia [*Sanguinolites*] *striato-lamellosa* (de Kon.).
Palæolima obliquiradiata (Hind).

GASTEROPODA.

Dentalium ingeus (de Kon.).
D. ornatum (de Kon.).
D. priscum (Goldf.).
Chiton coloratus (Kirkby).
C. burrovianus (Kirkby).
C. cordatus (Kirkby).
C. loftusianus (King).
Chitonellus subantiquus (K. & Y.).
Pileopsis [*Capulus*] *neritoides* (Phill.).
Capulus compressus (de Kon.).
C. dorsatus (de Kon.).
C. rectus (de Ryck).
C. fimbriatus (de Kon.).
Pileopsis [*C.*] *vetustus* (Sow.).
Bellerophon bicarenus (L'Ev.).
B. costatus (Sow.).
B. [*Bucania*] *decussatus* (Flem.) var.
B. [*Tropidocyclus*] *Dumonti* (F. D'Orb.).
B. hiulcus (Mart.).
B. Münsteri (d'Orb.).
B. tangentialis (Phill.).
B. tenuifascia (Sow.).
B. [*Euphemus*] cf. *filosus* (de Kon.).
Eulima [*Polyphemopsis*] *Phillipsiana* (de Kon.).
Euomphalus acutus (Sow.).
E. crotalostomus (McCoy).
E. (*Phanerotinus*) *angiostomus* (de Kon.).
E. (*Schizostoma*) *catilloides* (de Kon.).
E. (*Straparollus*) *Dionysii* (Goldf.).
E. (*S.*) *mammula* (de Kon.).
E. (*S.*) *fallax* (de Kon.).
E. lævigatus (L'Ev.).
E. pentangulatus (Sow.).
E. (*Straparollus*) *planorbis* (de Vern).
E. (*Phymatifer*) *pugilis* (Phill.).
E. (*Phanerotinus*) *vermicularis* (de Kon.).
E. convolutus (de Kon.).

Cirrus [*E.* (*Straparollus*)] *pileopsideus* (Phill.).
C. [*E.*] *spiralis* (Phill.).
C. [*E.*] *tabulatus* (Phill.).
Melania [*Loxonema*] *constricta* (Sow.), also Scaleber.
L. lefebvrei (L'Ev.).
Melania [*L.*] *rugifera* (Phill.).
M. [*L.*] *scalaroidea* (Phill.).
L. elongata (Flem.).
L. sulcatum (de Kon.).
Buccinum [*Macrocheilina*] *acutum* (Sow.).
B. [*M.*] *imbricatum* (Sow.).
B. [*M.*] *sigmilineum* (Phill.) var.
Macrocheilus [*M.*] *brevispiratus* (McCoy).
M. [*M.*] *michotianas* (de Kon.).
Metoptoma elliptica (Phill.).
M. oblonga (Phill.).
M. imbricata (Phill.).
M. pileus (Phill.).
M. sulcata (Phill.) ?
Trochus [*Microdorna*] *serrilimba* (Phill.).
Murchisonia abbreviata (de Kon.).
Rostellaria [*M.* (*Worthenia*)] *angulata* (Phill.).
Murchisonia Humboldtiana (de Kon.).
M. melanioides (de Kon.).
M. quadricarinata (McCoy).
M. verneuilliana (de Kon.).
M. Kendalensis (McCoy).
M. [*Aclisina*] *striatula* (de Kon.).
Natica [*Narica* (*Natiria*)] *lyrata* (Phill.).
N. [*Naticopsis*] *ampliata* (Phill.).
N. [*N.*] *elongata* (Phill.).
N. [*N.*] *plicistria* (Phill.).
N. Phillipsi (McCoy).
N. spirata (Sow.).
Orthonema sp.
Siphonaria [*Lepetopsis*] *Konincki* (McCoy).
Umbrella [*L.*] *lævigatus* (McCoy).
L. umbrella (de Kon.).

Patella [*L.*] *retrorsa* (Phill.).
L. undulatus (de Kon.).
L. ryckholtianus ? (de Kon.).
L. ellipticus (de Kon.).
Helcion [*L.*] *busscherianus* (Ryck).
Patella [*L.*] *sinuosa* (Phill.).
Pleurotomaria [*Platyschisma*] *glabrata* (Phill.).
Ampullaria [*P.*] *helicoides* (Sow.).
Pleurotomaria abdita (Phill.) ?
P. (*Luciella*) *angulata* (de Kon.).
P. (*L.*) *eliana* (de Kon.).
Helix [*P.* (*Mourlonia*)] *carinata* (Sow.).
P. (*Mourlonia*) *conica* (Phill.).
P. exarata (de Kon.).
P. (*Gosseletia*) *callosa* (de Kon.).
P. (*Rhineoderma*) *fragilis* (de Kon.).
P. gemmulifera ? var. (Phill.).
P. (*Mourtonia*) *virgulata* (de Kon.).
P. Hainessii (McCoy).
P. (*Ptychomphalus*) *inflata ?* (de Kon.).
P. benediana (de Kon.).
P. lœvis (McCoy) (?=*P. abdita* Phill.).
P. (*Luciella*) *limbata* (Phill.).
P. (*Mourlonia*) *naticoides* (de Kon.).
P. (*M.*) *compressa* (de Kon.).
P. (*Luciella*) *squamula* (Phill.) ?
P. (*Ptychomphalus*) *striata* (Sow.).
P. (*P.*) *dives* (de Kon.) ?
P. (*P.*) *tormatilis* (Phill.).
P. variata (de Kon.).
P. virgulata (de Kon.).
P. vittata (Phill.).
P. leveillii (de Kon.).
P. spirata (de Kon.).
P. (*Baylea*) *luxurians* (de Kon.).
P. (*Mourliana*) *aperta* (de Kon.).
P. (*M.*) *sulcifera* (de Kon.) ?
P. (*M.*) *expansa* (Phill.) ?

Porcellia puzo (L'Ev.).
P. [*Nautilus*] *Woodwardi* (Sow.).
Buccinum [*Portlockia*] *parallela* (Phill.).
P. amœna (de Kon.) ?
Natica [*Scalites*] *tabulata* (Phill.).
Trochus [*Microdoma*] *serrilimba* (Phill.).
T. (*Flemingia*) *hisingerianus* (de Kon.).
T. (*F.*) *laqueatus* (de Kon.).
T. (*F.*) *coniformis* (de Kon.).
T. tenuispira (de Kon.).
Turbo [*Turbonellina*] *lepida* (de Kon.).
T. [*T.*] *formosa* (de Kon.).
T. [*T.*] *pulchra* (de Kon.).
T. [*T.*] *pulchella* (de Kon.).
T. [*Turbonitella*] *biserialis* (Phill.).

CEPHALOPODA.

Orthoceras [*Actinoceras*] *breynii* (Mart.).
O. [*A.*] *giganteum* (Sow.).
O. [*A.*] *Sowerbyi* McCoy.
Nautilus [*Cœlonautilus* (*Vestinautilus*)] *biangulatus* (Sow.).
N. [*Coloceras*] *bistrialis* (Phill.).
N. [*Planetoceras*] *globatus* (Sow.).
N. [*Cœlonautilus ?*] *Edwardsianus* (de Kon.).
Discites bisulcatus (de Kon.).
Ellipsolithes [*Aphelceras*] *compressus* (Sow.).
Nautilus [*Phacoceras*] *oxystomus* (Phill.).
N. [*D.*] *planotergatus* (McCoy).
N. [*Stroboceras*] *sulcatus* (Sow.).
Goniatites [*Glyphioceras*] *vesica* (Phill.).
G. [*G.*] cf. *complicatum* (de Kon.) ?
G. [*G.*] *crenistrium* (Phill.).
G. [*G.*] *striatum* (Sow.).
G. [*G.*] *micronotum* (Phill.) ?
G. [*G.*] *mutabile* (Phill.) and Scaleber.
G. [*G.*] *obtusum* (Phill.).
G. [*G.*] *truncatum* (Phill.).
G. Phillipsi (Foord & Crick).

G. [*G.*] *Sphæricum* (Mart.).
G. [*G.*] *nitidum* (Phill.).
G. [*Brancoceras*] *rotatorium* (de Kon.).
G. [*Dimorphoceras*] *discrepans* (Brown).
G. [*Prolecanites*] *mixolobus* (Phill.).
G. [*P.*] *serpentinus* (Phill.).
G. [*Nomismoceras*] *vittiger* (Phill.).
Gyroceras propinquum (de Kon.).
G. approximatum (de Kon.).
G. intermedium ? (de Kon.).
Orthoceras cinctum (Sow.).
O. conquestum (de Kon.) ?
O. cylindraceum (Flem.).
O. filiferum (Phill.).
O. Gesneri (Mart.).
O. goldfussianum (de Kon.).
O. ovale (Phill.).
O. sagitta (de Kon.).
O. sulcatum (Flem.).
O. unguis (Phill.).
O. [*Poterioceras*] *fusiforme* (Sow.).
Nautilus [*Solenocheilus*] *crassiventer* (de Kon.).
N. [*S.*] *cyclostomus* (Phill.).
Temnocheilus coronatus (McCoy).

MARINE, AND OTHER, FOSSILS IN THE YORKSHIRE COAL MEASURES ABOVE THE BARNSLEY SEAM.

BY H. CULPIN.

(*Read 20th February,* 1908. *Manuscript received 8th October,* 1908.)

When the Geological Survey Memoir on the Yorkshire Coalfield was published in 1878, the records of fossils from the measures above the Barnsley Coal were very meagre. Dr. Wheelton Hind, in 1895, summarised in his Monograph on the "Carbonicola, Anthracomya, and Naiadites" (p. 162), the particulars given in the Memoir regarding the *Anthracosia* (*Carbonicola*); and added details as to similar shells obtained from the horizons of the Stanley Shale (Scale) and Stanley Main Coals at Wakefield. References to Mr. W. Hemingway's work in regard to plant remains will be found in the Proceedings of our Society for 1901 and 1902 (Vol. XIV., pp. 189-229 and 344-399), in Mr. R. Kidston's papers on the "Flora of the Carboniferous Period." In 1901, in the same issue of the Proceedings that contained the first of Mr. Kidston's two papers, a list of fish remains from the Lower and Middle Coal Measures was published by Mr. Edgar D. Wellburn (Vol. XIV., pp. 171-174). In this list, a copy of which appeared in a recent issue of the Society's Proceedings (Vol. XVI., Part II., 1907, p. 198), it is shown that fish specimens have been noted on five horizons, commencing with, and above, the Barnsley seam.

In 1905, also in our Proceedings (Vol. XV., p. 330), the discovery was recorded, for the first time I believe in Yorkshire, of *Anthracomya Phillipsi.* This was at Cadeby, in some Red Coal Measures, about ten feet below the base of the Permian rocks. Shortly afterwards the same shell was seen by Mr. A. Jordan in grey shales at the Conisborough Brick and Tile Works. It was subsequently recognised in grey rocks from the Balby boulder clay, and also in similar boulders from a sinking at Bentley, near Doncaster, where glacial débris, 20 feet thick, was found below a covering of 80 feet of river silt and clay.

Since these discoveries, a sinking has been successfully carried down to the Barnsley seam at Brodsworth, about four miles north-west of Doncaster, and as the result of watching the ground gone through (see Section, p. 333), some particulars have been obtained, which it is thought desirable to place on record, not only in regard to the range of *Anthracomya Phillipsi* and its allies, but also as to the existence of marine bands not hitherto recorded in Yorkshire.

But before mentioning these further, I should remind my readers that at the Annual General Meeting of our Society at Sheffield, in November last, as also at the Annual Meeting of the Institution of Mining Engineers in the same city, in September last, Mr. H. St. John Durnford recorded a marine band found 195 feet below the base of the Permian rocks in a deep boring at Barlow, near Selby (for account of this boring see pp. 337-346). Abundant fossil plants were found some 500 feet lower, and *Carbonicola acuta* and *Anthracomya* sp. occurred 100 feet below the plants. Mr. Durnford further stated that a bed with marine fossils had been proved in a boring at Wentbridge.

Mr. E. Hummel, of the Leeds University, has also been examining the Coal Measures recently, and has collected data which, when published, will add very considerably to our knowledge of the marine bands, and other features, in the Yorkshire Coalfield.

References to the fossils recorded in the publications mentioned, with the exception of those announced by Mr. Durnford, have been entered on a table (p. 334) of the Measures above the Barnsley Coal, which has been copied from the Geological Survey Memoir on the Yorkshire Coalfield. Further lists (pp. 327–331) summarise the records from the Brodsworth sinking.

In the table there is one marine band, with *Aviculopecten* (*Pterinopecten*), and it occurs not far below the Ackworth rock. *Posidonomya* (Mem. Geol. Yorks. Coalfield, pp 468 and 753), which is suggestive of another such band, is at a higher level, being immediately below the Houghton Common rock. At Brodsworth, where the Coal Measures were entered about 270 feet above the Ackworth rock, and probably 200 feet at least below the level of the Houghton Common rock, four marine bands were proved, and to these may now be added a fifth one recently passed through at Bentley, near Doncaster.

On the table *Anthracomya Phillipsi* appears only above the level of the Houghton Common rock. At Brodsworth it was found in great numbers above, and immediately below, the Ackworth rock. It also probably occurred below the Shafton Coal in association with *Anthracomya* cf. *minima*, and again, probably, as low down as the Abdy or Winter Coal in association with *Spirorbis*, *Naiadites modiolaris*, *Carbonicola aquilina*, and *Carbonicola* prob. *turgida*.

Summarily grouping other particulars contained in the table, *Carbonicola* appears immediately below the Houghton Common rock, and above and below the Wath Wood seam. *Carbonicola robusta*, *C. aquilina*, *C. turgida*, *Anthracomya Wardi*. *Naiadites modiolaris*, *N. triangularis*, and *N. carinata* are shown at the level of the Stanley Scale Coal; and *Carbonicola acuta* and *C. aquilina* at the level of the Stanley Main Coal. Fish, mentioned in the Survey Memoir (pp. 468 and 753) in only one position above the Barnsley seam, and then merely as fish, appear below the Houghton Common rock. Coprolites, which also probably indicate fish, are referred to (p. 791) as having been seen in the Stanley Shale. Mr. Edgar D. Wellburn has recorded six species of fish from the level of the Yard Coal, three from the Stanley Scale, four from the Kent's Thick, eight from the Cannel above the Thick Barnsley bed, and 29 from the Barnsley seam. Plants are quoted in the Memoir, now and again with the names, but usually only as *Stigmaria* or *Sigillaria*, first at Conisborough Pottery, and then, in descending order, at various levels, including the Woolley Edge rock. As found by Mr. W. Hemingway, and figured in Mr. Kidston's papers, the Houghton Common rock, the Woolley Edge rock, and the Barnsley seam, more particularly the latter, yielded rich results.

So far as the plants at Brodsworth are concerned, specimens were obtained above the Ackworth rock, above and below the Shafton Coal, above the Melton Field rock, which corresponds with the Woolley Edge rock, above the Abdy or Winter Coal, below the Kent's Thin, and very abundantly in the 100 feet above the Barnsley seam. Mr. R. Kidston has seen the specimens, and his determinations of them are entered on list, p. 331.

Fish remains were also found at several levels at Brodsworth. The whole of them have been examined by Mr. Edgar D. Wellburn, and those from the marine bands have also been submitted to Dr. A. Smith-Woodward. The results are shown on list, p. 329.

So far as the Mollusca (list, p. 327) are concerned, the presence of *Anthracomya Phillipsi* has already been dealt with. *Anthracomya Adamsii* probably occurred at as high a level as midway between the Shafton Coal and the Melton Field rock, but the specimens were too crushed for reliable determination. *Naiadites modiolaris* ranged from top to bottom. *Carbonicola aquilina* occurred above and below the Kent's Thick Coal, near the Abdy or Winter Coal, and probably above the Melton Field Coal. In the latter instance, the shells, as was frequently the experience in other instances, were much crushed, and I am afraid that Dr. Wheelton Hind, who generously went through the whole of the material for me, had a troublesome task. Among the crushed specimens were *Carbonicola* prob. *obtusa* from the roof of the Melton Field Coal, and *Carbonicola* prob. *turgida* found near the Abdy or Winter Coal, and also about 100 feet above the Barnsley Coal. *Anthracomya pulchra* occurred about 30 feet above the Kent's Thin Coal, with *Anthracomya* prob. *lævis*. I have already stated that *Anthracomya* cf. *minima* was seen below the Shafton Coal. It also occurred below the Melton Field rock.

Of the four marine bands seen at Brodsworth, the topmost was in 32 feet of "blue bind," the base of which was 106½ feet below the Ackworth rock. The fossils, so far as could be ascertained, came from the higher part of the "bind." They included *Lingula mytiloides*, *Pterinopecten papyraceus*, *Posidoniella lævis*, *Nuculana acuta*, and *Goniatites*. There were also abundant fish fragments, including *Megalichthys*. This band is most likely the same as that mentioned in the Survey Memoir (p. 471), as having been noted in a cutting east of Swan Hill on the Swinton and Knottingley line, below the Brierley or Ackworth rock, showing, as is there said, "that incursions of the sea continued to occur even up to these comparatively late portions of the Coal Measure period." At Brodsworth in this bed there were also occasional traces of plants (*Calamites* sp. and *Neuropteris heterophylla*), which presented an attractively delicate appearance when the shales containing them were first opened, but quickly deteriorated on exposure.

The next marine band proved to be the most important one of the series, and from its distinctive lithological and palæontological characters it should be a useful datum line for future borings and sinkings. It was about 15 feet thick, the base of it being 219 feet above the Melton Field Coal and 705 feet above the Barnsley Coal. At the top it consisted of blue shales with fucoid markings and with a soapy feel. Similar shales then followed which were crowded with *Lingula mytiloides*. Beneath these were greyish-blue hard shales, which in turn rested on an extremely hard, greyish-blue limestone "cank." The lower shales were very fossiliferous, and the limestone moderately so. The list includes three brachiopods (*Chonetes Laguessiana* mut. θ, *Lingula mytiloides*, and *Orbiculoidea nitida*) ; ten lamellibranchs (*Aviculopecten* sp. nov., described on p. 335 by Dr. Wheelton Hind as *A. Culpini*, *Ctenodonta lævirostrum*, *Myalina compressa*, *Nucula æqualis*, *Nuculana acuta*, *Pterinopecten papyraceus*, *Posidoniella sulcata*, *Pseudamusium fibrillosum*, *Scaldia* sp. nov., described on p. 335-6 by Dr. Wheelton Hind as *S. carbonaria*, and *Syncyclonema carboniferum*) ; one gasteropod (*Euphemus* sp.) ; six cephalopods (*Dimorphoceras Gilbertsoni*, *Glyphioceras micronotum*, *G. reticulatum* (?), *Orthoceras asciculare*, *O. Steinhaureri*, and *Pleuronautilus costatus*); seven fishes (*Acanthodes* sp., *Cœlacanthus* sp., *Elonichthys Egertoni*, *Megalichthys Hibberti*, *Rhadinichthys Monensis*, *Rhizodopsis sauroides*, and *Strepsodus sauroides*); and three plants (*Neuropteris heterophylla*, *N.* cf. *rarinervis*, and *Lepidodendron* sp.). Similar fossils are being obtained from the same band since proved at Bentley.

The third marine band at Brodsworth occurred above what I believe to be the Winter or Abdy Coal. The only Mollusca found in it were *Lingula mytiloides* and *Pterinopecten papyraceus*. The former were very numerous, some of them being notably small and others as notably large. At Bentley an examination of the same band in the shaft, which has been rendered possible by the keen interest taken in the fossil beds by the manager, Mr. R. Clive, and the surveyor, Mr. H. T. Foster, has shown that the small ones followed the large ones. At Bentley *Posidoniella sulcata* has also been found in this band. Fish fragments were abundant in this band at Brodsworth. They included *Acanthodes Wardi*, *Pleuroplax Rankinei*, *Cœlacanthus elegans*, *Rhadinichthys Monensis*, *Rhizodopsis sauroides*, and *Strepsodus sauroides*.

The fourth bed occurred at rather more than 100 feet above the Barnsley Coal. It yielded only *Lingula mytiloides* and a fish scale, which was probably *Rhizodopsis sauroides*. The shales in this bed, as also in the other marine beds, were blue or grey-blue, with a markedly soapy feeling.

This fourth bed has not yet been reached at Bentley, but there has been one with *Lingula mytiloides* and fish remains, about 90 feet below the principal marine band, thus making five marine bands in all, so far, in the two sinkings.

Thanks are due to Dr. Wheelton Hind, Dr. A. Smith-Woodward, Mr. Edgar D. Wellburn, and Mr. R. Kidston, for examining and naming the Mollusca, the fish fragments, and the plants. Also to Dr. Walcot Gibson for guidance and assistance in the work, and to the Brodsworth Main Colliery management for permission to examine the material and for information as to the depths.

List of Fossil Shells from Sinking at Brodsworth, 4 miles N.W. of Doncaster, Yorkshire.

Depth from surface. Ft.	190	250	271	280	290	310	450	530	536	540	577	610	637	640	651	658¾	700	750	840	920	998	1055	1062	1130	1207	1250	1280	1285	1300	1370	1385	1390	1455	1470	1500	1570	1650	1656	1700	1730	1740	1750	1765	1775	1776¼
Height above Barnsley Coal. Ft.	1577	1517	1496	1487	1477	1457	1317	1237	1231	1227	1190	1157	1130	1127	1116	1108¼	1067	1017	927	847	769	712	705	637	560	517	487	482	467	397	382	377	312	297	267	197	117	111	67	37	27	17	2		—
Annelida.																																													
Spirorbis sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	*	...	...	...	...	...	*	...	...	...	...	...	...	
Arthropoda.																																													
Entomostrarce ? Leperditia		...	...	...	...	...	...		...	*	...	..																																	
Brachiopoda.																																													
Chonetes laguessiana, mut. θ de Kon.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*																						
Lingula mytiloides, Sow.																							*															*							
Orbiculoidea nitida, Phill.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*																						
Lamellibranchiata.																																													
Anthracomya Adamsi, Salter	Base of the Permian.	...	...	...	...	...	...	Base of the Ackworth Rock (71 ft.).	...	...	...	...	...	...	...	Base of the Shafton Coal (5 ft. 2 in.).	...	...	...	?	...	...	...	...	Base of the Melton Field (Woolley Edge) Rock (72½ ft.)	...	...	Base of the Melton Field (Wath Wood) Coal (3½ ft.).	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Base of the Barnsley Coal (9 ft. 5 in.).
,, cf. *minima*		...	...	...	...	...	...		...	...	...	...	...	...	...		...	*	...	...	...	...	...	...		*	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *lævis*		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	
,, *Phillipsi*, Will.		...	...	...	*	...	...		*	...	...	...	...	...	?		...	?	...	...	...	...	...	...		...	...		...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	
,, *pulchra*, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	
,, sp.		...	...	...	...	...	...		*	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	
Aviculopecten Culpini, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Carbonicola acuta, var.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	*		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *aquilina*		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		?	...		...	?	...	*	...	...	...	*	...	*	...	...	...	...	...	...	
,, ,, var.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *obtusa*, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	?		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *turgida*, Brown		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	?	...	...	...	...	...	?	...	...	...	...	...	...	
,, sp.																																		*											
Ctenodonta lævirostrum, Portl.																																													
Myalina compressa, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Naiadites modiolaris, Sow.		...	...	...	*	...	...		*	*	...	...	...	...	...		...	...	*	...	...	...	...	...		...	...		...	...	...	*	...	...	...	...	...	*	...	...	...	...	...	...	
,, sp.		...	...	...	...	...	...		...	...	?	...	*	...	...		...	*	...	...	...	...	...	*		...	...		...	...	...	?	*	...	...	...	...	...	...	...	...	...	...	...	
Nucula æqualis		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Nuculana acuta		...	...	...	...	...	...		...	...	...	*	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Pseudamusium fibrillosum		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Pterinopecten papyraceus, Goldf.																																													
Posidoniella lævis, Brown																																													
,, cf. *lævis*		...	...	...	...	...	...		...	...	...	*	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	...												
,, *sulcata*, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Scaldia carbonaria, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...																		
Saneuclonema carboniferum, Hind		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Gasteropoda.																																													
Euphemus sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Cephalopoda.																																													
Dimorphoceras Gilbertsoni, Phill.																																													
Glyphioceras sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	...												
,, *micronotum*, Phill.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *reticulatum* (?), Phill.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...																		
Orthoceras asciculare		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
,, *Steinhaueri*, Sow.																	...	...	...	...	...	...	*																						
Pleuronautilus costatus		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...																		

LIST OF FOSSIL FISH REMAINS FROM SINKING AT BRODSWORTH, 4 MILES N.W. OF DONCASTER, YORKSHIRE.

PISCES.	Depth from surface Ft.	190	250	271	280	290	340	450	530	536	540	577	610	637	640	651	658½	700	750	840	920	998	1055
	Height above Barnsley Coal. Ft.	1577	1517	1496	1487	1477	1427	1317	1237	1231	1227	1190	1157	1130	1127	1116	1108½	1067	1017	927	847	769	712
ELASMOBRANCHII.		Base of the Permian.							Base of the Ackworth Rock (71 Ft.).								Base of the Shafton Coal ([illegible] Ft. 2 In.)						
Acanthodes Wardi, Egert.																							
,, sp.																							
Helodus simplex, Agass.																							
Pleuracanthus gibbosus, Agass.																							
Pleuroplax Rankinei, H. & A.																							
TELEOSTOMI.																							
Coelacanthus elegans, Newb.																							
,, sp.																							
Elonichthys Egertoni, Agass.																							
,, sp.																							
Megalichthys Hibberti, Agass.																							
Platysomus parvulus, Agass.																							
Rhadinichthys monensis, Egert.																							
,, sp.																							
Rhizodopsis sauroides, Williamson																							
Strepsodus sauroides, Binney																							

PISCES.	Depth from surface Ft.	1062	1130	1207	1250	1280	1285	1300	1370	1385	1390	1455	1470	1500	1570	1650	1656	1700	1730	1740	1750	1765	1775	1776¾
	Height above Barnsley Coal. Ft.	705	637	560	517	487	482	467	397	382	377	312	297	267	197	117	111	67	37	27	17	2	—	—
ELASMOBRANCHII.				Base of the Melton Field (Woolley Edge) Rock (72½ Ft.).			Base of the Melton Field Wath Wood Coal ([illegible] Ft. 11 In.)																	Base of the Barnsley Coal ([illegible] Ft. [illegible] In.)
Acanthodes Wardi, Egert.					*																			
,, sp.					...																			
Helodus simplex, Agass.					...																			
Pleuracanthus gibbosus, Agass.					...																			
Pleuroplax Rankinei, H. & A.					...																			
TELEOSTOMI.																								
Coelacanthus elegans, Newb.					*																			
,, sp.					...																			
Elonichthys Egertoni, Agass.					*																			
,, sp.					...																			
Megalichthys Hibberti, Agass.					...																			
Platysomus parvulus, Agass.					*																			
Rhadinichthys monensis, Egert.					*																			
,, sp.					...																			
Rhizodopsis sauroides, Williamson					*																			
Strepsodus sauroides, Binney																								

List of Fossil Plants from Sinking at Brodsworth, 4 miles N W. of Doncaster, Yorkshire.

PLANTÆ. Depth from surface. Ft.	190	250	271	280	290	340	450	530	536	540	577	610	637	640	651	658½	700	750	840	920	998	1055	1062	1130	1207	1250	1280	1285	1300	1370	1385	1390	1455	1470	1500	1570	1650	1656	1700	1730	1740	1750	1765	1775	1776½
Height above Barnsley Coal. Ft.	1577	1517	1496	1487	1477	1427	1317	1237	1231	1227	1190	1157	1130	1127	1116	1108½	1067	1017	927	847	769	712	705	637	560	517	487	482	467	397	382	377	312	297	267	197	117	111	67	37	27	17	2		
FILICACEÆ.	Base of the Permian.							Base of the Ackworth Rock (71 Ft.)								Base of the Shafton Coal (5 Ft. 2 In.).									Base of the Melton Field (Woolley Edge) Rock (72⅓ Ft.).			Base of the Melton Field (Wath Wood) Coal (3⅓ Ft.).																	Base of the Barnsley Coal (9 Ft. 5 In.).
Mariopteris muricata, Schloth.		...	...	...	...	...	...		...	...	...																																		
Neuropteris gigantea, Sternb.		...	*	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, *heterophylla*, Brongt.		...	...	...	...	...	...		...	...	...	*	...	...	...		...	...	...	...	*	*	*	...		...	...																		
,, *obliqua*, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		*	...	...	...	...	...	...	...		...	...																		
,, cf. *rarinervis*, Bunb.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...																		
,, cf. *tenuifolia*, Schloth. sp.		...	...	...	...	...	...		...	...	...	...	...	*	...		...	...	...	...	...	...	...	...		...	...																		
,, sp.		*																																											
Sphenopteris acuta, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, *gracilis*, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
Corynepteris Sternbergi, Ett. sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
EQUISETACEÆ.																																													
Annularia radiata, Brongt				*																																									
,, sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
Calamites, sp.		...	...	...	...	...	...		...	...	...	*	...	...	...		...	*	...	*	...	...	...	...		...	...																		
,, *ramosus*, Artes.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, *Suckowi*, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
LYCOPODIACEÆ.																																													
Lepidodendron aculeatum, Sternb.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, cf. *fusiforme*, Corda sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		*	...	...	...	...	...	...	...		...	...																		
,, *ophiurus*, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, ,, *forma dilatatum*, L. & H. sp.		...	...	...	*	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
,, *rimosum*, Sternb.		...	...	...	...	...	...		...	...	...	...	...	...	...		*	...	...	...	...	...	...	...		...	...																		
,, sp.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	*	...		...	...																		
Lepidophyllum, sp.		*																																											
Lepidostrobus variabilis, L. & H.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	*		...	...																		
Stigmaria ficoides, Sternb.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...																		
CORDAITEÆ.																																													
Trigonocarpus Parkinsoni, Brongt.		...	...	...	...	...	...		...	...	...	...	...	...	...		...	...	...	...	...	...	...	...		...	...		...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	

SECTION OF SINKING AT BRODSWORTH, 4 MILES N.W. OF DONCASTER, YORKSHIRE.

SURFACE OF GROUND 122 FT. ABOVE ORDNANCE DATUM.

	Thickness.		Depth from Surface.	
	Ft.	In.	Ft.	In.
Superficial	1	8	1	8
Permian Middle Marls	77	9	...	
			79	5
Permian Lower Limestone	110	3	...	
Coal Measures entered at	...		189	8
Coal	1	0	278	6
Coal and bat	1	11	282	1½
Coal	1	4	343	11
Coal		3	374	10½
		3½	375	4
Coal		8	427	10
Coal	1	0	435	5
ACKWORTH ROCK	71	0	...	
BASE	...		530	2
Coal		3	542	3
MARINE BAND	...		610	0
In blue bind	32	2	636	8
SHAFTON COAL	5	2	658	6
Coal		6	669	3
Coal		6	732	0
Coal	1	6	808	8
Coal		11	981	2
MARINE BAND in blue bind	20	4	1062	0
MELTON FIELD (WOOLLEY EDGE) ROCK	72	6	...	
BASE	...		1206	11
Coal		4	1210	10
Coal	1	9	1214	0
MELTON FIELD (WATH WOOD) COAL	3	6	1284	10
TWO FOOT COAL	1 1	4 1	1340 1359	8 7
MARINE BAND	...		1385	0
ABDY COAL	2	0	1386	6
Coal		9	1391	3
BEAMSHAW COAL	2	3	1419	9
Coal (2 in. at 1421 ft. 2 in. and 4 in. at 1421 ft. 10 in.)	...		1458 to 1461	4½ 3½
Coal 6½ in., Coal and dirt 6 in., Coal 8 in., and Coal 4½ in.	...			
KENT'S THIN COAL	1	9	1489	7
Coal 4 in. and 2 in.	...		1532	1
Coal		1	1563	0
KENT'S THICK COAL	1 1	3 1	1583 1611	8 9
MARINE BAND	...		1656	0
BARNSLEY RIDER COAL	1	8	1725	8
Coal		2	1764	0
BARNSLEY COAL	9	5	1776	5

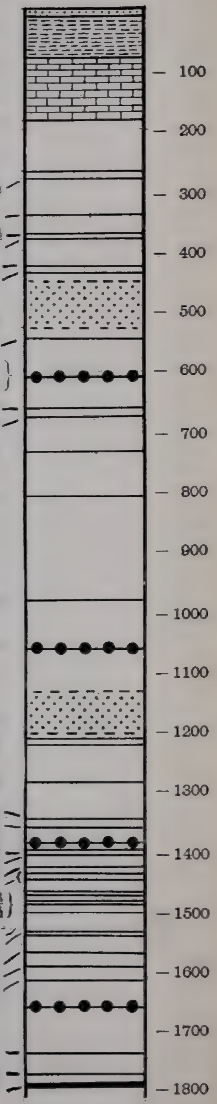
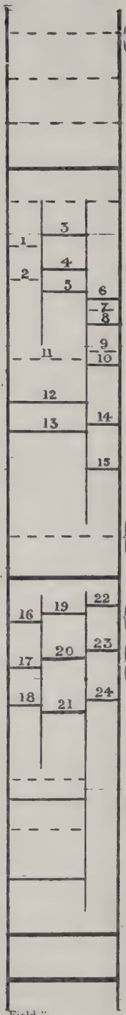
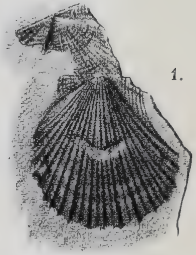


TABLE OF THE YORKSHIRE COAL MEASURES ABOVE THE BARNSLEY COAL.

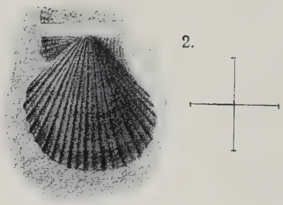
Red Beds with Coal Plants of Conisborough Pottery (M., p. 75)			*Anthracomya Phillipsi* (Y.G.S., 1905, p. 330). *Neuropteris*, *Sphenopteris*, *Stigmaria* (M., p. 480).
Measures			*Stigmaria* (M., p. 478).
Wickersley, Houghton Common, and Pontefract Rocks			*Artisia transversa* (K.).
Measures			*Posidonomya*, *Carbonicola*, and Fish (M., pp. 468 and 753). *Cypris* (M., p. 468).
Dalton, Brierley, and Ackworth Rocks			*Calamites approximatus*, *Sternbergia approximata*. *Halonia regularis* (M., p. 470).
Measures			*Aviculopecten* (M., p. 471).
Shafton or Nostel Coal			
Upper Chevet Rock			
Measures with **Middle [1] and Lower [2] Chevet Rocks and Thin Coals.**	Measures with **Sharlston Top [3], Low [4], and Yard [5] Coals.**	Measures with **Holywell Wood Coal [6].** Measures with **Houghton Rock [7].** **Houghton Coals [8].**	*Stigmaria* (M., p. 771). *Sigillaria* (M., p. 459) [4].
Tree'on Rock, Oaks Rock, or equivalent Measures [11].		Measures with **Ackton Rock [9], Wheatworth Coal [10].**	
Measures with **Newhill or Steam Coal [13] and Swinton Pottery Coal [12].**		Measures **Bateson's Bed [14].**	*Stigmaria* (M., p. 443) [13].
		Measures with **Castleford Four-foot Coal [15].**	
Woolley Edge Rock, or equivalent Measures			*Dadoxylon*, *Lepidodendron*, *Calamites*, &c. (M., p. 437). Plants (K., per Hemingway).
Aston Common, Wath Wood, Woodmoor, and Wakefield Muck Coals			*Carbonicola* (M., pp. 414 and 768).
Measures **Foxearth Coal [16].**	Measures **Two-foot Coal [19].**	Measures **Cat Coal [22].**	Fish (W.) [17 and 23]. *Coprolites* (M., p. 791 and Simpson, Y.G.S., 1844)
Measures **Sough or Yard Coal [17].**	Measures **Abdy or Winter Coal [20].**	Measures **Stanley Scale Coal [23].**	*Carbonicola robusta*, *C aquilina*, *C. turgida*, *Anthracomya Wardi*, *Naiadites radiolaris*, *N triangularis*, *N. carinata* (Hind, p. 162).
Measures **Furnace Coal [18].**	Measures **Beamshaw Coals [21].**	Measures **Stanley Main Coal [24].**	*Carbonicola acuta*, *C aquilina* (Hind, p. 162).
Measures with **Kent's Thin Rock.**		? Absent North of Wakefield.	
Kent's Thin Coal.			*Stigmaria* (M., pp. 404 and 695).
Measures with **Kent's Thick Rock.**			
High Hazles, Kent's Thick, and Mapplewell Coals.			Fish [Kent's Thick Coal] (W.).
Measures with **Barnsley Rider Coal and Barnsley Rock**			
Barnsley, Warren House, and Gawthorpe Coals			Fish (W.). Plants (K., per Hemingway).



NOTES.—M.=Geol. Sur. Memoir, "Geology of the Yorkshire Coal Field."
Y.G.S. = Proc. Yorks. Geol. and Polytec. Soc.
K. = Kidston.
W. = Wellburn.
Hind = "Carbonicola, Anthracomya, and Naiadites."
The numbers, &c., in square brackets refer to the diagram.



1.



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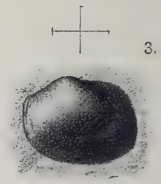


3.

Figs. 1 and 2.—AVICULOPECTEN CULPINI.

Fig. 3.—SCALDIA CARBONARIA.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XL.

DESCRIPTION OF TWO NEW SPECIES OF LAMELLIBRANCHS FROM MARINE BANDS OF THE YORKSHIRE COALFIELD.

BY WHEELTON HIND, M.D., B.S., F.R.C.S., F.G.S.

(*Manuscript received* 14*th November*, 1908.)

AVICULOPECTEN CULPINI, sp. nov. Plate XL., Figs. 1 and 2.

Specific Characters :—Shell small; quadrate. The left valve moderately convex. The hinge line straight, produced and pointed posteriorly. Ears large, deep, and well defined, the anterior with six deeply-impressed radiating grooves separated by ridges; the posterior concave, with one central, thin, radiating ridge and numerous fine concentric striæ; its margin arcuate. The body of the valve is ornamented with many radiating, sharp raised, equidistant, slightly nodulose ribs, some of which start at the umbo, but as they become separated in their passage across the shell, new ones arise between each pair.

The right valve has a somewhat similar ornament, but the radiating lines are much finer and the whole valve is much flatter.

Dimensions :—A left valve measures: Antero-posteriorly, 12 mm.; Dorso-ventrally, 12 mm.

Localities :—Brodsworth and Bentley.

Observations :—Mr. Culpin has been fortunate enough to find a left valve of this shell at both Brodsworth and Bentley. It belongs to the group of *A. tabulatus*, being characterised by a very long spur along the upper border of the posterior ear. The Bentley specimen shows the external ornament. The Brodsworth specimen is the interior of the valve and has the ears perfectly preserved. I figure a specimen with two valves from Bentley.

SCALDIA CARBONARIA, sp. nov. Plate XL., Fig. 3.

Specific Characters :—Shell small, orbicular, gibbose. Margin formed by a single curve which passes from the anterior extremity of the hinge line without any break to the posterior, the curvature becoming somewhat flattened along the posterior border. Hinge line arcuate. Umbo small, pointed, sub-central. The shell is regularly swollen, but somewhat compressed towards the posterior superior angle.

Exterior :—The shell is ornamented with very fine concentric lines of growth.

Dimensions :—A left valve measures : Antero-posteriorly, 7 mm. ; Dorso-ventrally, 7 mm. ; Gibbosity of valve, 1 mm.

Localities :—Brodsworth ; Wentbridge Boring, 193 and 333½ feet from the surface.

Observations :—I refer this species without hesitation to *Scaldia*, although I have not seen the hinge. It has been found by Mr. Culpin at Brodsworth, and by Mr. E. Hummel at two horizons in the Wentbridge Boring.

The species is much larger than *Scaldia minuta*, Hind, from the Coal Measures of North Staffordshire, but smaller than the Carboniferous Limestone species, and the concentric markings are much finer than in the latter species.

GEOLOGICAL NOTES ON A DEEP BORING NEAR SELBY.

BY H. ST. JOHN DURNFORD, M.INST.C.E.

(*Read November,* 1907. *Manuscript received,* 13*th December,* 1907.)

The writer believes there has been more than one deep boring put down in the neighbourhood of the old town of Selby, but in some instances no record has been published of the results obtained, either on account of carelessness or because the undertakers of the boring wished to keep the information obtained to themselves. Fortunately, in the present instance, the owner of the land on which the boring was situated, the Rt. Hon. the Earl of Londesborough, who bore the expense of the experiment, has made no such stipulation, and as a careful record of the strata passed through in the boring was kept, the information is open to those who may be interested in such an undertaking. The results from a practical point of view are not insignificant, and from a geological standpoint most interesting.

The position of the borehole can be seen by reference to the map accompanying these notes (Fig. 1). It is situated towards the south-east of the Great Plain of York on the right bank of the River Ouse, three miles east-south-east of Selby. As is well known the stratigraphy of the Plain of York is obscure, the surface being covered for the most part with alluvial drift which, although valuable and useful from a farmer's and landowner's standpoint, is often somewhat disconcerting to the geologist. In the immediate neighbourhood of Selby, however, two landmarks stand out, known as Brayton Barf and Hambleton Hough. These two eminences, neither of which rises more than 125 feet above the surrounding plain, are conspicuous objects from afar. They are exposures of the Triassic Sandstone, cropping up from under the superficial alluvium, and in going east from Leeds are the first evidences of the Trias to meet the eye. At the foot of the larger hill of the two—Brayton Barf—the Selby Corporation have recently put down a borehole in connection with their water supply, which hole has been carried to a depth of about 600 feet and yields a considerable feeder of water.

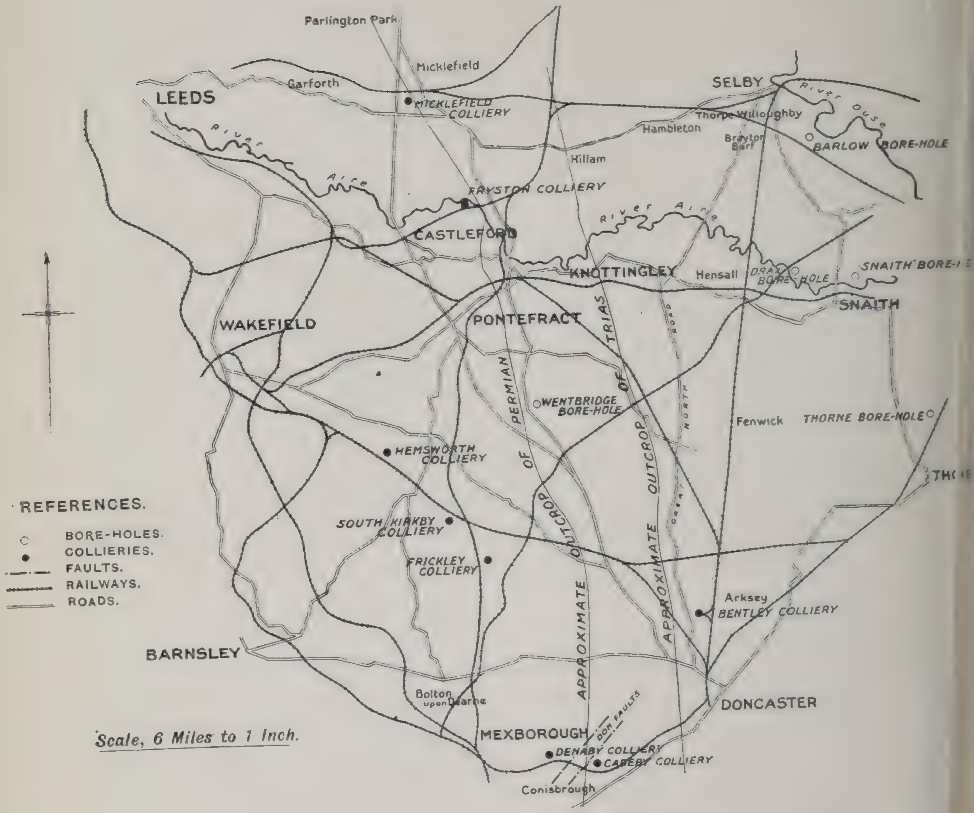


Fig. 1.

The nearest working collieries to the site of the hole are Micklefield (about 12½ miles distant in a north-westerly direction), and Fryston Collieries (about 11 miles south-west), where the Beeston Bed is worked at depths of 750 feet and 1,620 feet respectively. The Coal Measures at these two places are dipping south-east, and it was to be expected that at Barlow the seams of the Lower Coal Measures would prove to be at a very considerable depth from the surface. The primary object of the borehole was to prove the existence of Coal Measures and the depth at which they lie in Lord Londesborough's estate.

In settling the site for the borehole more weight was attached to position from a geographical standpoint with proper access to the river and railways crossing the property than to the best position geologically. In fact, as little or no reliable information was available, it would have been difficult to decide on any other grounds.

Professor Kendall has very kindly lent a map showing the boundary of the Yorkshire and Nottinghamshire Coalfield as suggested by various authorities from time to time. The brown line is the limit as suggested by the late Professor Green before the 1871 Commission, the outer blue line as suggested by Professor Hull, and the red line as suggested by Professor Kendall in his report to the Royal Commission of 1905. From this map it will be seen that although the site of the hole was chosen as far south as the boundaries of the estate would permit, it was not very far from the supposed northern limit, being in fact almost on Professor Green's line, two miles south of Professor Hull's, and seven miles south of Professor Kendall's.

Turning now to the consideration of the strata passed through, the first 75 feet proved to be alluvial sands, gravels, and clays. Beneath this superficial deposit the Triassic Rocks were met with—presumably the Bunter Beds. Whether the Keuper Beds exist at Barlow or not appears to be an open question. Those passed through, however, consisted of coarse red and occasional grey sandstones presenting no features of particular interest until at a depth of 690 feet a series of marls and gypsum bands was entered, which proved to be about 120 feet in thickness. The Bunter Pebble Beds, so well developed in Cheshire and Shropshire, were very meagrely represented, if at all. In the absence of fossil evidence it is difficult to decide whether the series of marls referred to belongs to the Permian or the Trias. It would appear probable that it belongs partly to both divisions, and that no definite horizon can be taken as the transition from Permian to Trias, but that the one merges into the other. Beds of red marl constituted the first 50 feet of the series, being followed by beds of gypsum and anhydrite. These beds of anhydrite are very persistent throughout the district, and were proved in borings at Snaith, Thorne, and

South Car. The gypsum is most probably identical with the beds quarried at Hillam for the manufacture of plaster of Paris. At a depth of 820 feet the Magnesian Limestone was entered, which it is safe to assume is Permian in age. The Permian as proved at Barlow may be classed in three sub-divisions, viz. :—(1) The Upper Magnesian Limestone ; (2) Middle Marls ; and (3) Lower Magnesian Limestone. The Upper Limestone was a fairly consistent deposit some 90 feet thick, interspersed with an occasional thin band of gypsum. The Middle Marl Series was a little over 100 feet in thickness. In the middle of the series occurred a bed of rock salt 20 feet thick. This rock salt appears to be a local deposit, but if it were proved to be of any considerable extent it might possibly, in the future, form a valuable asset to the estate. The rest of the strata consisted of Red Marls, with an occasional layer of limestone and a bed of anhydrite. The Lower Magnesian Limestone, occurring between 1,010 and 1,305 feet, was similar in character to the Upper Limestone. No fossils were discovered in the cores obtained from the Permian, though a few shells are to be found in the quarries at Garforth, where the Permian outcrops, e.g., *Productus horridus* and *Bakevellia Sedgwickiana*.

At a depth of 1,305 feet the sudden transition from Permian to Carboniferous took place—lithologically from magnesian limestone to grey shale. The strata proved below this depth consisted of typical Coal Measure shales and sandstones, the only unusual feature being the entire absence of workable coal seams. Without going into needless detail of each stratum, the writer will content himself with calling attention to points of special interest. At a depth of 1,500 feet a shaley band occurred containing numerous specimens of *Pterinopecten papyraceous* and one or two goniatite impressions. Unfortunately the latter were not sufficiently well preserved to enable their species to be determined. This marine band was one foot in thickness, and overlay a bed of fire-clay. The bed of dark coloured shales at 1,600 feet contained concretionary ironstone, and at 1,615 feet a coal seam was met with 1 foot 3 inches in thickness. The coal did not form a core, but was brought up in the chip cup in a fragmental condition. The seat earth was a bed of fire-clay four feet in thickness. Beds of fire-clay were also passed through at 1,760 feet and 1,776 feet, being one foot and four feet thick respectively. The stone, bind and shales occurring between 2,000 feet and 2,040 feet yielded an adundant fossil flora of the type so common in the Coal Measures. A considerable number of the ferns were submitted to Mr. Robert Kidston, who identified the following species :—*Sphenopteris*, sp. *Neuropteris heterophylla*, *N. tenuifolia*, *Alethopteris decurrens*, and *A. lonchitica*. Numerous calamites and some stigmaria and rootlets were also obtained from the cores. Mr. Kidston said that from the character of the ferns he was distinctly of the opinion that they had been obtained from Middle Coal Measure strata, probably well up in the series. It may be mentioned that this was also the opinion of Mr. Walcot Gibson, of the Geological Survey. At 2,100 feet a fresh water bed was proved containing fairly numerous lamellibranchs, viz. :—*Anthracomya* sp. and *Anthracosia acuta*. The writer believes geologists place considerable reliance on these fresh-water mollusca as a means of zoning the Coal Measures, and that in some coalfields a fair amount of success has attended their endeavours. Unfortunately, the species found at Barlow are, the writer believes, common throughout the Coal Measures, and are therefore of little value in this respect. It has been thought that the marine bands might be useful as a guide in correlating the freshwater beds, and in passing the writer might mention that the *Pterinopecten* and the goniatite impressions obtained from the marine band at 1,500 feet bear a very close resemblance to fossils obtained from a boring at Wentbridge, near Pontefract. The writer was indebted to Mr. E. L. Hummel, now of Whitwood Colliery, in that he was enabled to exhibit the two sets of fossils side by side, and to show that they were almost indistinguishable. Whether this fact is of any particular significance is more a question for a geologist than for a mining engineer.

A coal seam, three feet thick, was met with at 2,120 feet. A core was obtained, but the coal was very hard and apparently of inferior quality. The seam was underlaid by eight feet of fire-clay. The cores obtained from the last 200 feet or so were considerably broken up, and at some places—particularly at depths of 2,170 feet and 2,200 feet—showed distinct evidence of faulting. The cores obtained from the depths named were of a very crushed and dirty nature, and were very distinctly slickensided. The cores obtained from lower depths were sounder, but the apparent dip of the strata, which in the Coal Measures had steadily increased with the depth of the hole, was so high—as much as 70° to 80°—that a great deal of boring had to be done to prove very little thickness of strata, and as it seemed likely that further boring would only deepen the disappointment felt at not proving workable coal seams, operations were discontinued when a total depth of 2,371 feet had been attained.

A rough survey of the hole was made, which proved a deviation of about 12° from the vertical near the bottom. Assuming that the deviation took place in the same direction as the dip of the strata—and to a practical man this seems most reasonable—the high inclination of the strata as shown in the cores would thereby to some extent be explained. As, however, the apparent dip was as high as 70° at depths where the proved deviation of the hole was only 12°, it is evident that the actual dip at that point would be 58 degrees. A somewhat perplexing feature already mentioned was the increase of the apparent dip as shown in the cores with the depth of the hole. Two explanations offer themselves, viz. :—(1) That the deviation of the hole in the line of the dip increased rapidly with the depth of the hole, and that the actual dip of the strata was constant, or (2) that the strata were folded, and that the hole went down through the limb of an anticlinal or monoclinal fold. The first explanation is not in accordance with the observed facts, inasmuch as near the top of the Coal Measures, where the hole was nearly vertical, the dip shown in the cores was only slight. The second theory is probably correct. The diagram (Fig. 2) has been prepared to illustrate the effect of an anticlinal fold on the dip of the strata as observed in the cores from a borehole, and the effect shown is very much in accordance with the observations made at Barlow. Professor Kendall, in his report to the Coal Commission, expounds his opinion on the question of northern boundary of the coalfield, and demonstrates very clearly the existence of a "persistent" anticline of pre-Permian date extending across the Vale of York, from which we gather that the Coal Measures have been denuded off this anticline with the result that the Permian rests directly on the Millstone Grit. Professor Hull shows the northern boundary as a large fault, or series of faults, running west to east, but the writer cannot see that this is justified, inasmuch as the faults existing at the northern extremity of the exposed coalfield have not, to his knowledge, been proved under the newer rocks to the east. The matter is, however, very thoroughly dealt with in Professor Kendall's report. It would seem probable that the hole was put down not very far south of Professor Kendall's Wharfe-Market Weighton axis, and that the striking variation of the dip is accounted for by the folding of the strata, perhaps not the actual Wharfe anticline, but some secondary and more acute fold of possibly only a local nature.

It has been suggested, doubtless with a great deal of truth, that the seams of the Middle Coal Measures might exist in normal conditions and of normal thickness in the neighbourhood, but that on the limb of the fold through which it is supposed the borehole passed they have diminished in thickness or thinned out altogether. Mr. Emsley Coke has suggested that the beds of fire-clay passed through

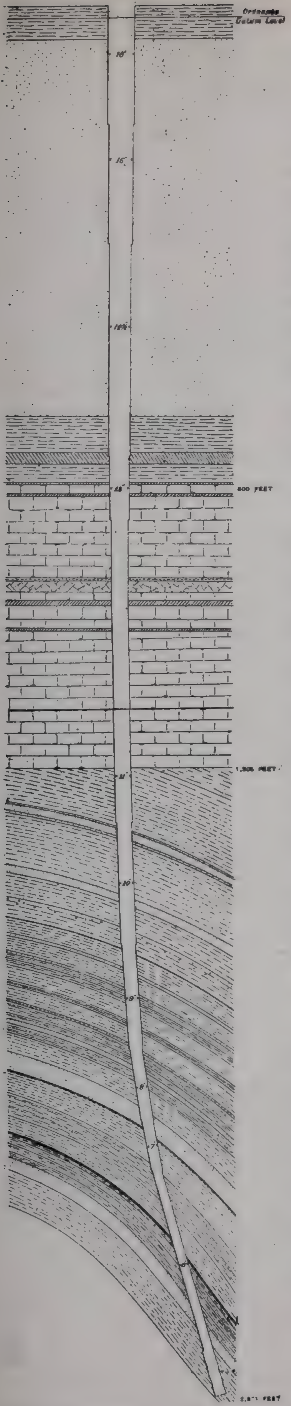


Fig. 2.—SECTION OF THE BARLOW BOREHOLE.

are the seat earths of coal seams which have disappeared at the point where the hole was put down owing to the abnormal and probably merely local conditions existing.

In conclusion the writer thinks the fact that 1,050 feet of Coal Measures have been proved by the hole to some extent justifies the undertaking, and should be an incentive to further borings in the neighbourhood more to the west, or at any rate clear of the site of the hole at Barlow, in order to prove the valuable coal seams which doubtless exist in the district.

The writer expresses his appreciation of the interest taken by so many gentlemen in the undertaking, and his thanks to those who have given him the benefit of their experience.

APPENDIX.

SECTION OF STRATA IN A BORE-HOLE NEAR SELBY, IN THE PARISH OF BARLOW, COUNTY OF YORKSHIRE, DURING 1904-1906. LATITUDE 53° 45′ 20″ AND LONGITUDE 1° 2′, AND 16·1 FEET ABOVE ORDNANCE DATUM-LEVEL.

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
	Alluvium.				
1.	Dark-brown clay	24	0	24	0
2.	Brown clay: friable	14	0	38	0
3.	Red sand	1	0	39	0
4.	Clay	15	0	54	0
5.	Sand	18	0	72	0
6.	Red sand	22	0	74	0
	Trias.				
7.	Red sandstone: broken	56	0	150	0
8.	Red sandstone	50	0	200	0
9.	Red sandstone: friable	80	0	280	0
10.	Mottled red marl	2	0	282	0
11.	Red sandstone	8	0	290	0
12.	Red sandstone: solid	197	0	487	0
13.	Red sandstone	95	0	582	0
14.	Red sandstone, mixed with marl	43	0	625	0
15.	Grey sandstone	45	0	670	0
16.	Red sandstone	2	0	672	0
17.	Red marl	1	0	673	0
18.	Red sandstone	22	0	695	0
19.	Red marl	6	0	701	0
20.	Red marl, with sandstone layers	4	0	705	0
21.	Red and mottled marl	10	0	715	0
22.	Red marl	4	0	719	0
23.	Red marl and sandstone	1	0	720	0

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
	Trias—continued.				
24.	Red marl	34	0	754	0
25.	Gypsum	2	0	756	0
26.	Gypsum	1	0	757	0
27.	Anhydrite	4	0	761	0
28.	Anhydrite	13	0	774	0
29.	Red marl : friable	0	6	774	6
30.	Marl and gypsum-bands	5	0	779	6
31.	Red marl : friable	16	6	796	0
32.	Marl, with bands of gypsum	4	0	800	0
	Magnesian Limestone.				
33.	Limestone, with bands of gypsum	16	0	816	0
34.	Limestone	4	0	820	0
35.	Limestone	35	6	855	6
36.	Limestone : jointy	38	0	893	6
37.	Limestone, with bands of shale and gypsum	10	0	903	6
38.	Red marl, with layers of limestone	64	0	967	6
39.	Rock-salt	20	0	987	6
40.	Limestone	20	6	1,008	0
41.	Blue marl	1	0	1,009	0
42.	Anhydrite	5	6	1,014	6
43.	Blue marl	1	0	1,015	6
44.	Limestone	4	6	1,020	0
45.	Red marl	1	0	1,021	0
46.	Limestone	25	6	1,046	6
47.	Limestone, with veins of gypsum	45	0	1,091	6
48.	Limestone	137	6	1,229	0
49.	Limestone : honeycombed and jointy	35	0	1,264	0
50.	Limestone	41	0	1,305	0
	Coal Measures.				
51.	Grey shale	12	0	1,317	0
52.	Blue shale	2	0	1,319	0
53.	Blue shale	29	0	1,348	0
54.	Grey shale	28	0	1,376	0
55.	Dark shale	18	0	1,394	0
56.	Blue shale	12	0	1,406	0
57.	Sandstone and sandy shale, with *coal* veins	15	0	1,421	0
58.	Blue shale, with sandstone layers	19	0	1,440	0
59.	Blue shale	60	0	1,500	0
60.	Fire-clay	1	0	1,501	0
61.	Blue shale	18	0	1,519	0
62.	Light-coloured sandy shale	7	0	1,526	0
63.	Blue shale	45	0	1,571	0
64.	Grey shale	6	0	1,577	0
65.	Dark-coloured shale, with ironstone nodules	7	6	1,584	6
66.	Sandy shale	4	6	1,589	0
67.	Dark-blue shale	26	0	1,615	0
68.	COAL	1	3	1,616	3
69.	Fire-clay	4	0	1,620	3
70.	Blue shale	29	9	1,650	0
71.	Grey shale and sandstone layers	32	0	1,682	0
72.	Blue shale	9	0	1,691	0

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
	Coal Measures—continued.				
73.	Stone-bind	13	0	1,704	0
74.	Dark-blue shale	27	0	1,731	0
75.	Fire-clay	1	0	1,732	0
76.	Sandstone	4	0	1,736	0
77.	Stone-bind	8	0	1,744	0
78.	Blue shale	24	0	1,768	0
79.	Dark-coloured shale	4	0	1,772	0
80.	Fire-clay	4	0	1,776	0
81.	Stone-bind	5	0	1,781	0
82.	Light-coloured shale	6	0	1,787	0
83.	Dark-coloured shale	13	0	1,800	0
84.	Light grey sandstone	14	0	1,814	0
85.	Blue shale, very friable	5	0	1,819	0
86.	Stone-bind	18	0	1,837	0
87.	Blue shale	3	0	1,840	0
88.	Stone-bind	2	0	1,842	0
89.	Blue shale	41	0	1,883	0
90.	Grey sandstone	41	0	1,924	0
91.	COAL	0	9	1,924	9
92.	Fire-clay	4	0	1,928	9
93.	Shale: rotten	48	3	1,977	0
94.	Blue shale	7	0	1,984	0
95.	Stone-bind	74	0	2,058	0
96.	Blue shale	61	0	2,119	0
97.	COAL: inferior	3	0	2,122	0
98.	Fire-clay	8	0	2,130	0
99.	Light-coloured stone	40	0	2,170	0
100.	Blue shale	8	0	2,178	0
101.	Light-coloured stone	17	0	2,195	0
102.	Blue shale, with *coal* veins	22	0	2,217	0
103.	Grey sandstone	63	0	2,280	0
104.	Blue shale	91	0	2,371	0

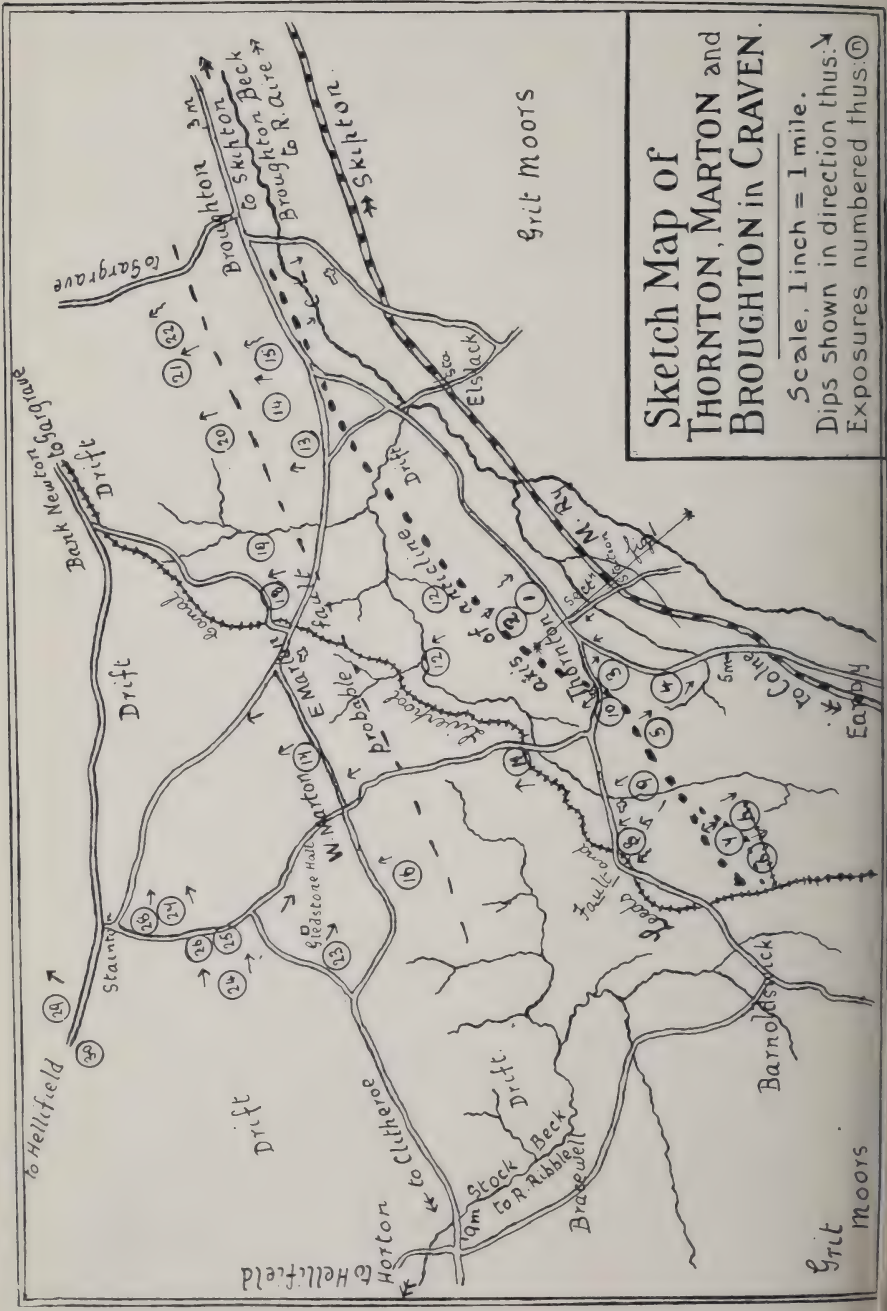
NOTES ON THE GEOLOGY OF THORNTON, MARTON, AND BROUGHTON-IN-CRAVEN, YORKSHIRE.

BY A. WILMORE, B.Sc., F.G.S.

(*Read 20th February,* 1908. *Manuscript received 14th November,* 1908.)

The district with which this paper deals forms part of the celebrated "Craven pasture ground." It lies at the western end of the Craven or Aire Gap, and the Leeds and Liverpool Canal traverses it on its way through the Pennines. It is low, undulating country, varying in height from 300 to 700 feet, most of it lying between 400 and 600 feet O.D. It is drained by a number of small winding streams, probably the outcome of an inherited drainage. These streams wind in and out among the low rounded hills with which the district is studded, meandering through the "mosses" or alluvial flats, the drained "meres" which form the low fertile grass lands for which this part of Craven is so famous. Marton is said to be the tun or town by the mere.

Much of the district is covered with glacial deposits of very variable nature and thickness, and in the opening up of the numerous quarries it has usually been necessary to remove a considerable quantity of drift. The quarries are consequently found on the slopes or near the summits of the low hills. I do not know, in the low flat lands, a single cutting which has reached the solid rock below. There is a good typical section of Boulder Clay, containing striated boulders of limestone and green grit (probably Silurian), lying on the upturned edge of the limestone, in a quarry at Punch Bowl Hill, half a mile south-west of Thornton-in-Craven. It is close to the west side of the road from Skipton to Colne. Exposure (4) on the sketch map, p. 348. The rounded hills which form such a characteristic feature of the district have a tendency towards a linear arrangement, the general direction being the same as the strike of the folds. Where a transverse stream collects the waters of two



Sketch Map of THORNTON, MARTON and BROUGHTON in CRAVEN.

Scale, 1 inch = 1 mile.
Dips shown in direction thus: ↗
Exposures numbered thus: ⓝ

or more of the small longitudinal streams, the low hills are thus separated into roughly linear sets. There are also numerous "dry valleys," both of a longitudinal and transverse nature.

There are numerous quarries, many of them now largely grown over, though a few give occasional employment to two or three men, and one at Thornton-in-Craven is worked on a large scale. There is no lime-burning carried on nowadays, the stone being quarried for road metal and for "asphalt chippings." Of course the fences, except those in the drift-covered areas, usually consist of limestone walls. In the eight or ten square miles with which this paper deals, there are over 30 quarry cuttings known to the writer, and a few small road-side sections. The rivers seldom furnish sections.

The limestone is almost exclusively dark in colour, almost black in many cases, but weathering grey or brownish-grey on exposure. More rarely it weathers somewhat yellow. It is always quite well-bedded, usually thinly bedded, and in almost every quarry there are partings of shale. Veins of calcite are common almost everywhere, and occasionally veins of barytes are seen. Fluor occurs, but it is quite rare, and hydrated iron oxide is present in small quantity in irregular patches. There appears to be very little trace of galena.

Some remarks on the lithology of the district will be found, with the descriptions of the various quarries, in the following pages, and photographs of thin sections of some of the rocks are given on Plates XLI. to XLV.

Almost every exposure, and certainly every one of considerable size, shows signs of the disturbance to which the rocks of the district have been subjected. I do not know a large cutting which does not show abundant slickensiding or faulting or bending of the beds, and occasionally—as at Gill Rock for instance—all three evidences of disturbance are seen in one quarry.

There is no continuous section in the district, and as the dips change very rapidly, often in the same cutting, it is not easy to correlate the various beds or to estimate the thickness of strata exposed. The occurrence of so much drift adds to the difficulties of study.

The so-called "Clitheroe-Skipton anticlinal" is here replaced by lesser folds partly separated and displaced by faults. There is a well-defined anticline extending from near Barnoldswick through Thornton towards Broughton. Between Thornton and Broughton it is dissected by the transverse stream, Crickle Beck or Gill Beck, which comes from the East Marton district to join Broughton Beck at Elslack. The southern limb, which is so conspicuous further west, has been eroded away in the neighbourhood of Broughton by Broughton Beck, and the transverse beck just referred to, and we have low drift-covered country with few exposures. Those near Broughton Church show southerly dips and seem to correspond with the Thornton quarry and Rain Hall beds further west. They are mostly grown over, however, and those in the stream have proved very barren of fossils. It seems to me that the portion of country south of the main road, marked C.L. on the sketch map, should be coloured dark-blue, and I do not see the need for the fault shown at Broughton Fields (see One-inch Geological Map, New Series, Sheet 68, Clitheroe). The south-eastern limit of this anticline may be studied in numerous sections over a distance of about two miles, but the northern limit is more largely obscured by drift.

A fault is mapped along the northern limb from near Bracewell, by Langber, to the neighbourhood of Broughton. The evidence for this fault is given in the Geological Survey Memoir (" Burnley Coalfield," pp. 30–31). I submit that this fault should be continued towards Clint's Delf, that is north of Broughton Fields, and thus along the line of the branch fault of the survey. In my opinion, the beds at Broughton Fields, the three quarries, (13), (14), (15), in the sketch map, represent the northern limb of the Thornton anticline, the southern limb having been largely dissected out as mentioned above.

An irregular syncline lies to the north of this anticline, extending from near Horton by the south of Gledstone and apparently continuing towards Bank Newton and Gargrave. The district north-east of East Marton is, however, much obscured by drift.

North of Gledstone Hall, near West Marton, the strike of the beds changes completely, becoming almost north and south, and a series of exposures show dips almost due east, and there is a well-marked ridge with limestone scars. At the northern end of this series of exposures the dips change to north and north-east, while a little further afield north-westerly dips are seen. Hence there may be here a long hog's-back ridge with the western limb obscured by drift towards Horton.

I will describe the beds in the following order :—

I.—Those of the Thornton Anticline, (1) to (15) on sketch map.

II.—Those of the Marton to Clint's Delf Series, (16) to (23) on sketch map.

III.—The Marton Scar and Stainton Beds, (24) to (30) on sketch map.

I.—The Thornton Anticline.

About a quarter of a mile north-east of Thornton village there is a large quarry worked by Messrs. P. & W. Spencer.* There is no great thickness of beds exposed, as the quarry is being worked along the strike. The limestone is hard and dark in colour, and is very well bedded. There are shale beds of somewhat variable thickness, and it is from these calcareous shales that I have obtained most of my fossils. There is much calcite and some iron-oxide. The dip is from 60° to 70° south-south-east, but the direction varies slightly. The faces of the rock exposed by the quarrying operations show much slickensiding. As the quarrying operations are continued the beds are seen to have been subject to much disturbance. Compare Rain Hall, Gill Rock, &c.

I have carefully worked this quarry for some years, and I do not think any important types can have escaped my notice.

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* I beg to record my indebtedness to Messrs. Spencer for permission to visit their various quarries.

I have endeavoured to get some knowledge of the relative abundance of the various fossils.

CORALS :—

Syringopora ramulosa (Goldfuss), quite common.
S. ramulosa, variety *x* (see notes at end of paper).
Aulopora (?)
Zaphrentis Omaliusi (Edwards and Hanne), common.
Z. Omaliusi var. *densa* (R. G. Carruthers), very common.
Z. Omaliusi var. *ambigua* (R. G. Carruthers), not common.
Michelinia sp., rather rare.
Caninia cylindrica (Scouler), very rare.
Amplexus coralloides (Sow.), very rare.

Echinodermata and Polyzoa are very common, and I have a good collection, but very few of them have been worked out.

BRACHIOPODS :—These are usually crushed and fragmentary, and it is rarely possible to obtain complete specimens, though impressions of shell fragments are common enough. The following have been identified :—

Athyris planosulcata (Phillips), fairly common.
A. cf. *glabristria* (Vaughan), fairly common.
A. Royssi (L'Eveillé), rare.
Seminula of *ambigua* type.
Orthotetes crenistria (*Streptorhynchus crenistria*, Phillips).
O. cf. *Bristolensis* (Vaughan).
Rhipidomella Michelini (L'Eveillé), common.
Reticularia imbricata (McCoy), rare.
Spirifer bisulcatus (Sow.), rare.
Productus pustulosus (Phillips), fairly common.
P. scabriculus (Martin).

MOLLUSCA :—The common forms are :—

Lamellibranchs :—*Conocardium Hibernicum* and *C. aliforme.*
Gasteropod :—*Flemingia spiralis* (De Koninck).

These three molluscs are very common, and I have handled hundreds of the Gasteropod named.

A little to the north-west of the great quarry, on the other side of the long ridge-like hill, there is a somewhat overgrown cutting showing calcareous shales and muddy limestones, with bands of more massive and purer limestone. The same beds are seen in the lane leading from Thornton towards Langber and East Marton and are numbered (2) on the sketch map. Fossils are difficult to obtain, but I have found crinoid stems and plates, *Syringopora ramulosa*, and fragments of shells, amongst which *Athyris*, probably *planosulcata*, and *Orthotetes*, probably *crenistria*, were recognisable. These beds are apparently lower in the series than those in the larger exposure.

In the road leading from Thornton village to the station, a recent cutting revealed calcareous shales and limestones dipping at a low angle towards the north-west. There is obviously some disturbance here, faulting or folding or both. Near Thornton Hall, also in a road-side cutting, the beds dip into the hill, again showing disturbance along the northern limb of the anticline. These abnormal dips are mentioned in the Survey Memoir (p. 31), and it is suggested that they are probably due to dragging over of the beds by glaciers coming from the north. But the recent cutting, for the purpose of laying down a sewer, showed a persistent low dip to west of north, and I would suggest that here is a sharp fold and that a diagrammatic section drawn from north-west to south-east would show beds as in Fig. 1. See sketch map, Thornton village.

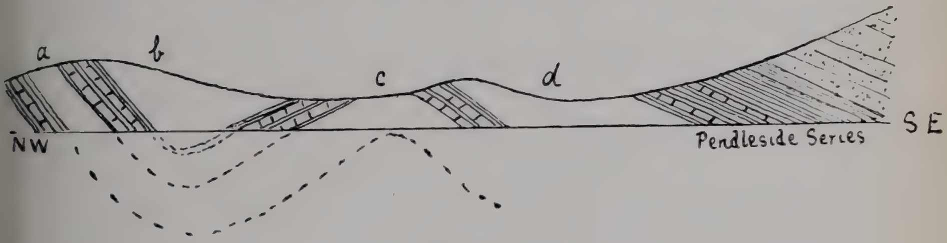

Fig. 1.

SECTION THROUGH THORNTON VILLAGE TO THE GRIT HILLS AT ELSLACK MOOR.
At *a*, *b*, *c*, *d* there are no exposures. Horizontal Scale, 3 in. = 1 mile.

The next exposure is that numbered (3) on the sketch-map. It is a little west of Thornton Hall. The beds are the same dark-blue to black limestones with calcareous shales, and dip south-south-east at about 30°. The exposure is now too much overgrown to allow of much collecting. I have obtained *Syringopora*, *Zaphrentis*, and *Athyris*, apparently of the same species as at Thornton Quarry.

Further to the south-west, near the top of Punch Bowl Hill, is the quarry with the covering of glacial deposits mentioned in the introduction (p. 347) and marked (4) on the map. Here are massive dark-blue to black limestones, with abundant calcite veins and some iron oxide, the dip being about 50° south-east. The limestone is a " foraminiferal mud " (see Plate XLI., Fig. 1). There are quite subordinate shale bands, and from those in the upper beds of the cutting I have obtained small fragments of *Zaphrentis*, probably *Omaliusi*, and a *Syringopora* of *ramulosa* type with very narrow tubes. Shells are very rare. I have only succeeded in obtaining *Athyris planosulcata* and a species of *Seminula*.

It is obviously very difficult to correlate these beds exactly, but I should say that they are probably a little higher than those of Thornton Quarry.

The exposure (5) is the quarry close to the new Golf Club House (Ghyll Golf Club). It has been known as South Field Quarry, but I propose to speak of it as the Golf Links Quarry. We have here again massive dark limestones with abundant shale. One shale bed is six feet in thickness, is black, and contains much carbonaceous matter. The more calcareous shale bands contain numerous fossils. The dip is here about 30°, as against 50° in the last quarry, with the same general direction (south-east), and there is a small fault visible.

The fossils are :—

CORALS :—

Zaphrentis, not at all common, diligent searching having only furnished a very few specimens.

Syringopora ramulosa, with fairly wide tubes, very common.

BRACHIOPODS :—

- *Athyris planosulcata ;* specimens are sometimes 1½ inches in width.
- *Orthotetes crenistria*, very common.
- *Chonetes Hardrensis* (Phillips).
- *Productus pustulosus.*
- *P. scabriculus.*
- *P. sublœvis* (Kon.).

The limestone of this quarry, when sectioned, shows numerous foraminifera, along with fine detritus of shells, corals, and echinodermata. There is one band of "shell breccia," in which fragments of shells, chiefly Athyrids, occur in a matrix containing much iron-carbonate, which weathers to hydrate.

I take it that these beds, possibly along with those of Rain Hall Plantation, represent the lowest beds seen in this anticline.

The next important exposure is that of Rain Hall Quarry, number (6) on map. This is classic ground, having been visited by Phillips. The Geological Survey Memoir describes it at some length ; and Messrs. Hind and Howe refer to it in their paper on the Pendleside beds at Pendle Hill, &c.

It is a long quarry, following the strike of the beds, and it has a branch of the Leeds and Liverpool Canal running almost to the limits of quarrying operations. It has long been disused and is now partly grown over. There is much disturbance, and at the western end the dip changes considerably and the beds become almost vertical. At the eastern end there is also some "rolling." Near the middle of the quarry there is a small fold, and beds are seen with a dip to north-north-west,* this part, however, being much grown over. The general dip is south-south-east, at an angle varying from 50° to 70°. There is much slickensiding, and some of the shales are strongly contorted, it being possible to obtain hand specimens which are as much contorted as some of the schists of, say, Anglesea.

The same type of dark limestone occurs, but there is also a grey crinoidal breccia, which is not represented in the quarries already described. This bed contains abundance of *Caninia cornucopiæ*, Mich., and I refer to it as the Caninia bed. There are also calcareous shales of considerable thickness, best seen at the south-western end. Veins of calcite and occasional occurrences of Barytes are seen.

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* I have to thank Mr. T. E. Brown for calling my attention to this.

Brown and black shales form the lower beds, then come dark limestones, followed by the Caninia bed, more dark limestones, and then black shales complete the sequence here.

The maximum width of the cutting is about 50 yards, and if we take the average dip as 60°, this would give a maximum thickness of 120 feet. The upper beds are very much like those of Gill Rock Quarry, and the Caninia bed occurs there unmistakably.

Collecting is not nearly so profitable here as in Thornton Quarry, because of the lack of exposed material, and because of the difficulty of reaching the beds. The accessible beds are fairly fossiliferous, excepting, of course, the dark massive limestones. The following types occur :—

CORALS :—

Syringopora ramulosa.
Zaphrentis Omaliusi, var. *ambigua.*
Caninia cornucopiæ.
Michelinia sp.

Echinodermata and Polyzoa plentiful. *Platycrinus* does not seem quite so common as at Thornton.

BRACHIOPODS :—

Athyris planosulcata.
Seminula, a small form.
Orthotetes crenistria.
O. cf. *Bristolensis* (Vaughan M.S.).
Chonetes Hardrensis.
Productus pustulosus.
P. semireticulatus (Martin).
P. sublævis.
Spirifer bisulcatus.
Rhynchonella pleurodon (Phillips).
Rhipidomella Michelini.

GASTEROPODS :—

Flemingia spiralis, and others not determined.

LAMELLIBRANCHIATA :—

Conocardium Hibernicum.

C. inflatum.

It will be seen how very similar the assemblage is to that of Thornton. I have not, however, succeeded in obtaining more than one specimen of *Rhipidomella Michelini*. *Conocardium* is also much rarer, whilst *Chonetes* is quite common here and rare at Thornton. The corals are mostly *Caninia*; the Zaphrentids occur in the lower beds, but sparingly, whereas Thornton simply teems with *Zaphrentis Omaliusi.*

There is a small quarry, No. (7) on the map, which is not now in use, about 120 yards north-west of the eastern end of Rain Hall. Here the beds dip north-west at an angle of about 40°. Thus the beds have turned over and we are on the northern limb of the anticline. There is local disturbance, however, as the beds present the appearance sketched in Fig. 2.

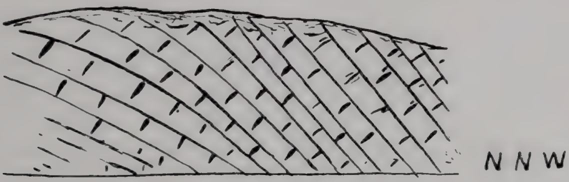

Fig. 2.

SKETCH OF BEDS IN SMALL QUARRY, RAIN HALL PLANTATION.

The limestones are here more flaggy and break with a sharp ringing sound. Impressions of *Orthotetes crenistria* are very common. *Chonetes*, probably *Hardrensis*, occurs. *Productus pustulosus* and *P. semireticulatus* are also common. I have also found one specimen of *Rhynchonella.*

Athyris planosulcata of large type occurs, as at Golf Links Quarry. I think that these beds are the same as those of the quarry just mentioned. They are very similar lithologically, and the fossils seem almost identical.

A very few yards to the west there are black calcareous shales, with thin limestones similar to the beds in the road-side cutting near Thornton Church and containing the same fossils.

I suppose that the relation of these beds to those of Rain Hall is as shown in Fig. 3.

There is a new exposure which is of great interest in its relation to the Rain Hall beds. A quarry near Long Ing Canal Bridge, that is near the western end of Rain Hall Quarry, has recently been opened. It shows the Caninia bed of Rain Hall and the overlying dark blue limestone. The beds dip north-west, so that here we have the turn over of the beds quite close at hand. This exposure is not more than 50 yards from the western end of Rain Hall Quarry. It is noteworthy that there is again much slickensiding seen.

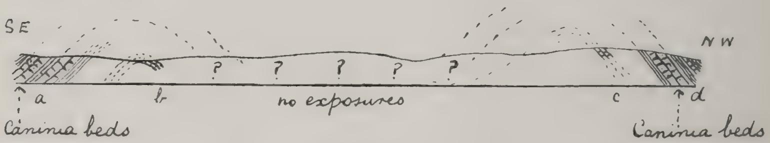

Fig. 3.

SUGGESTED DIAGRAM-SECTION ACROSS RAIN HALL AND GILL ROCK BEDS, DISTANCE 1,000 YARDS.

a=Rain Hall. *b*=Rain Hall Plantation. *c*=Small cutting near Gill Church. *d*=Gill Rock.

The next important exposure is that of Gill Rock, near Gill Church—No. (8) on the map. It is a large cutting now partly grown over. At the western end quarrying operations have been re-commenced, however. The beds dip at a high angle to north-north-west, and the Caninia bed of Rain Hall is almost at the bottom of the series. These beds are described by Phillips, by the officers of the Survey, and by Messrs. Hind and Howe. The sequence is as follows :—

Shales with thin limestones (like those of Salterforth cutting).
Crinoidal band.
Shales.
“ Dun stone.”

Shales.
Thin limestones.
Shales.
Dark limestone.
Caninia bed.
Black shales.

The Caninia bed consists of crinoidal and shell débris, exactly like that of Rain Hall, and it contains *Caninia cornucopiæ* in abundance, as well as *Michelinia*, which weather out just as they do at Rain Hall. There can be no doubt of the identity of the bed in the two quarries. The officers of the Survey took the base of the Upper Shales as the upper limit of the Carboniferous Limestone.

There is considerable disturbance here again. There is a famous fault, which was sketched by Phillips and again in the Survey Memoir. It is a fault with an almost vertical hade (see Plate XLVI., Fig. 1).

The distance from Rain Hall Plantation to the edge of Gill Rock is almost exactly 800 yards. Given a dip of 60°, this would mean a thickness of 1,600 feet. But the beds between Rain Hall Plantation and Rain Hall Quarry cannot be more than about 240 feet thick. Add to this, say, 60 feet before we get to the Caninia beds, and we have a thickness of not more than 300 feet. There must be much folding between Rain Hall and Gill Rock, and the estimate of 1,000 feet or so, given by the officers of the Survey, seems much more than is warranted. I should say that 300 feet or so is the maximum thickness of these beds, all of which are of high D type, probably all D_3.

There is little of importance to write concerning the exposures numbered (9) to (15) on the map. The rocks in the Gill itself, near Gill Church, are almost completely overgrown. A small exposure in the road side near Thornton Church, (10) on the map, shows beds of the same type as Rain Hall Plantation, with exactly the same fossils. There is here a small bay in the north side of the long hill of the anticline, and the road winds along the side of this bay. We thus get into the middle of the anticline and see the same lower beds as at Golf Links and Rain Hall Plantation cuttings.

The small cuttings at Langber and at Haw Pasture, (12) on the map, have furnished very few fossils. Small specimens of *Athyris*, probably *planosulcata*, and a small *Chonetes* being the only recognisable shells obtained, but fragments of *Syringopora* were also seen.

As the anticline is followed to the east it is found to be cut transversely by the brook, as already mentioned. The northern limb forms a well-marked ridge, extending from Broughton Fields to Broughton village, and in that ridge is a series of quarries, in which the beds have a steady north-westerly dip. They are numbered (13), (14), (15) on the sketch-map. In number (15) there is considerable disturbance, two small faults and some folding of the beds being seen. In number (13), the quarry at Broughton Fields, *Syringopora* is very common, and on the dip-slopes may be seen lenticular masses from six inches to a foot in diameter. Similar masses are seen in the calcareous shales at Rain Hall. (See note on *Syringopora* on page 368.) Other fossils are not common ; but such as I have obtained seem exactly like those of Rain Hall.

The beds in the whole of the exposures in this long anticline are of the same general type—calcareous shales, thin earthy limestones, massive dark-blue to black limestones, and subordinate grey crinoidal limestones being everywhere seen. The shales are characterised by the same general fauna, and the dark-blue and black limestones, when sectioned, present very similar features. Foraminifera are very plentiful. This is the case at the western end of the anticline, as at the Punch Bowl Hill and Gill Rock on opposite sides of the arch, and at Broughton Fields much further east. I have added a section from the well-known quarry at Raygill, Lothersdale, some 2½ miles south of the southern limb of the Thornton anticline (Plate XLIII., Fig. 1). It will be seen that the sections of these rocks show very similar characters to those of Thornton and district.

With regard to the precise stratigraphical position of the beds in this anticline, it must be pointed out that there is nothing like a continuous section, and that the beds are evidently very much disturbed. Still I think there is little doubt that they are of Upper Dibunophyllum age, probably corresponding with

D_3 of the South-western Province. Dr. Wheelton Hind and Dr. Vaughan have kindly examined some of the specimens of corals, brachiopods, and lamellibranchs collected by the author, and with respect to several have referred to them as "high D" and some more definitely to D_3.

Mr. R. G. Carruthers has kindly examined many of the corals, and with respect to some he says that they indicate a probable Upper Visean facies; but he points out that the assemblage of corals is an uncommon one, and that they alone would not fix the precise horizon.

It will be seen that it is not by any means easy to precisely correlate the beds with those of other provinces, still I think there is great probability that the whole thickness comes within the Upper Visean, probably D_3. Fortunately there is little doubt that near Rain Hall, at Gill Rock, and at Elslack they are definitely succeeded by the Lower Pendleside beds with their characteristic fauna. A quarry at Bawmier, very near to Rain Hall, shows limestone of undoubted Pendleside type, and in the next field grits come in. These are clearly the beds of Salterforth cutting, where *Posidonomya Becheri* occurs and the Pendleside fauna is well developed.

I propose, provisionally, to divide these beds into three stages, and to regard the whole as a sub-zone corresponding to the Amplexi-Zaphrentis sub-zone of the British Association Committee in the report for 1906. The three stages are characterised as follows:—The lowest zone seems to contain few corals, but swarms with *Orthotetes crenistria.* The impressions of this shell have a striking likeness in the three exposures which I believe to represent this stage, namely Golf Links Quarry, Rain Hall Plantation, and Thornton Church. Davidson's Fig. 19, Plate XXV., Brit. Carb. Brach., represents it fairly well, the curved striæ especially seeming much like the very numerous specimens found in those beds. The figure is possibly a little too long and narrow to accurately interpret most of the impressions I have seen. The next stage, seen in the Thornton beds and in the lower beds of Rain Hall, contains abundance of *Zaphrentis Omaliusi*, with its two varieties, *densa* and *ambigua.*

I have recently obtained good specimens of *Z. ambigua* (kindly identified for me by Mr. Carruthers) from the very lowest beds of Rain Hall, and it would seem that this variety predominates there. Still I have not been able to find corals in anything like the numbers I have obtained at Thornton. In the latter place *densa* seems to predominate. These beds I propose to call the Zaphrentis stage. The third stage is characterised by the abundance of *Caninia cornucopiæ* in a crinoidal breccia. This occurs well up in the Rain Hall beds, but nearly at the base of the Gill Rock beds. It also occurs in the new quarry near Long Ing.

In this bed at Rain Hall there are occasional shells and rarely a species of *Michelinia* ; at Gill Rock the same shells and the same *Michelinia* are found. This Caninia bed has exactly the same appearance in every respect in the three quarries mentioned, and where it has been weathered the appearances are also exactly the same. There can be little doubt of its identity in these exposures. In this stage I should include the dark, almost "unfossiliferous" foraminiferal limestone, which immediately overlies the Caninia bed in the three quarries. We should thus have the following sequence :—

Lower Pendleside Beds.

Upper Dibunophyllum sub-zone : { Caninia stage.
Zaphrentis stage.
Crenistria stage.

I realise that this is only provisional, and that a great deal more work must be done in these somewhat unfossilferous and disturbed strata before one can correlate more decidedly with the beds of the other provinces.

II.—Second Series of Exposures.

We now come to the series of exposures immediately north of the probable fault which runs from near Bracewell to the country north of Broughton. The evidence for the existence of this fault is given in the Geological Survey Memoir on the Burnley Coalfield, pp. 30 and 31. I do not accept the view that the beds of Marton "are certainly a long way down in the series." I do not know of any possible evidence except that of the fossils, and these do not warrant such a conclusion. The beds seem to me to be pretty much on the same horizon as those of the Thornton anticline.

There are several fairly good exposures, and fossils may be obtained in most of them, though not in any great profusion, except in those of Marton School and Clint's Delf. In all of them the dip is north of west, varying from about 15° to 50°, but generally not more than 20°. A notable feature of the lithology is the large amount of chert that is found in the beds of East Marton and in the small quarries slightly further east—Nos. (19) and (20) on map. The chert occurs in thin layers of from one inch to about four inches in thickness, and also in somewhat irregular lumps. It is sometimes seen to contain crinoid fragments.

The highest beds which can be studied seem to be those of Marton School, East Marton Old Quarry, and Clint's Delf—Nos. (17), (18), (22) on map. Here there is always the great abundance of crinoidal limestone that characterises the upper beds of the Carboniferous Limestone in the Thornton anticline, and that is prevalent in the higher beds of the same limestone in the Clitheroe-Downham district. The stems and plates of Echinoderms are beautifully preserved in Clint's Delf. The calcareous mud in which they occur crumbles very readily and these fossils may be picked up by hundreds.

Here again, as in the Thornton anticline, there are shale bands, or "shale-partings," as they are called locally, separating the massive dark limestones. It is from these shale bands that the most perfect fossils are usually obtained. The massive limestones, which are bluish-black on fracture, weather to yellowish-grey, and as the fine matrix is slowly eroded away, the megascopic fossils—corals, crinoids, shells—begin to stand out from the weathered rock surfaces. In this way the most unpromising solid rock, when it has been left exposed in the old quarries for years, often reveals very good fossils.

There is the same general assemblage of fossils all along the series. The chief types, neglecting the crinoids and the polyzoa, are as follows :—

CORALS :—

Syringopora ramulosa (Goldfuss).

Syringopora sp., with smaller, close-set tubes, rather unequally spaced, very much like Vaughan's *Syringopora* cf. *reticulata*.* The tubes are slightly larger as a rule, but the grouping and the relation of the connecting tubes seem to be the same.

Zaphrentis Omaliusi var. *densa* (R. G. Carruthers), var. *ambigua* (R. G. Carruthers), and a new variety not named.

Caninia cornucopiæ (Michelin), probably mutation d.

Caninia sp. nov.

Cyathaxonia Rushiana (Vaughan), and probably a new species of *Cyathaxonia*.

Michelinia sp. ; the same form as at Rain Hall, Gill Rock, and Thornton.

BRACHIOPODS :—

Rhipidomella Michelini (L'Eveillé). This is very common and seems exactly the same as the Thornton form.

Athyris cf. *planosulcata* (Phill.).

Orthotetes crenistria. Apparently the same as that from Rain Hall Plantation.

Productus pustulosus (Phill.).

P. semireticulatus (Mart.).

P. margaritaceus (Phill.).

Chonetes Hardrensis (Phill.).

C. papilionacea (Phill.).

The latter has a hinge line reaching to over four inches in length. The forms are much like Davidson's figure, Pl. XLVI., Fig. 3.

Spirifer bisulcatus (Sow.).

Rhynchonella pleurodon (Phill.).

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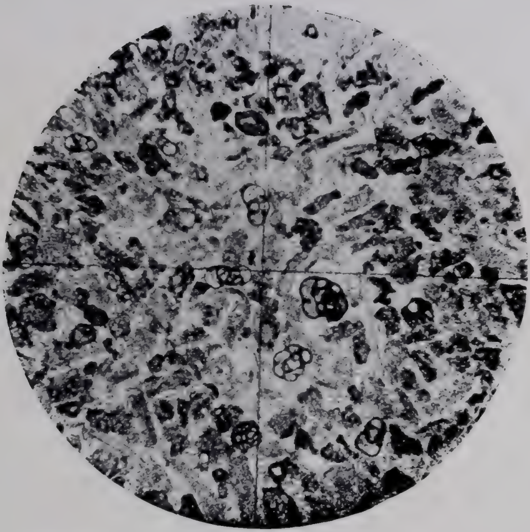
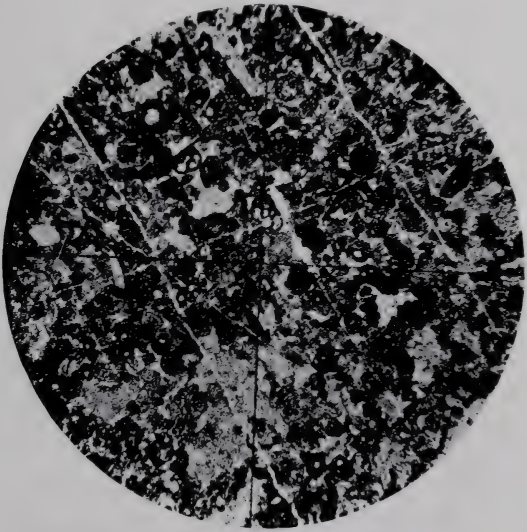
* Q.J.G.S., Vol. LXII. No. 246, Plate XXIX., and p. 313.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1. × 20.

HARD DARK LIMESTONE, EARBY-THORNTON ROAD, PUNCH BOWL HILL.

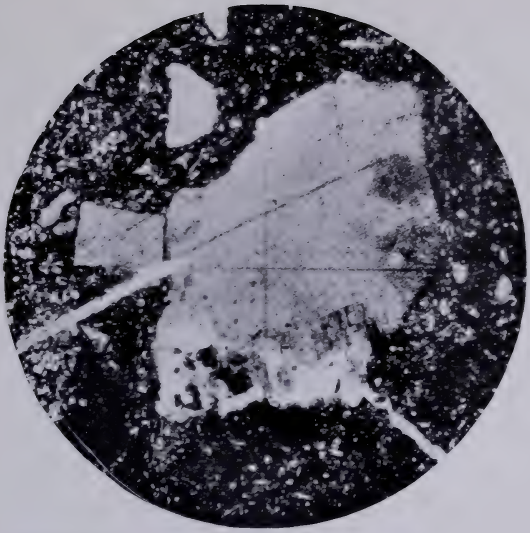


Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2. × 20.

HARD BLUE LIMESTONE, GILL ROCK, CRAVEN.

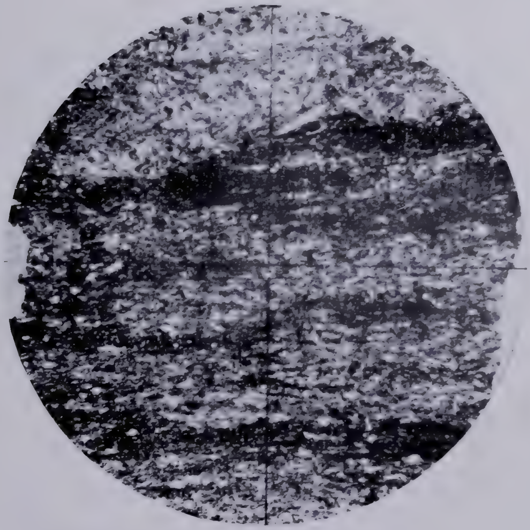
Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLI.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1. × 12.

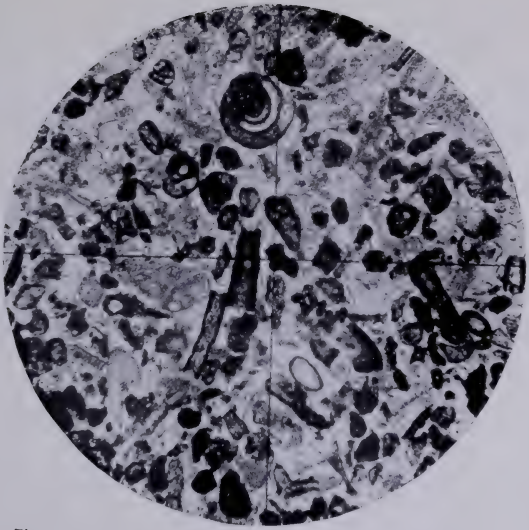
LIMESTONE WITH LARGE CRYSTAL OF CALCITE, MARTON SCHOOL.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2. × 12.

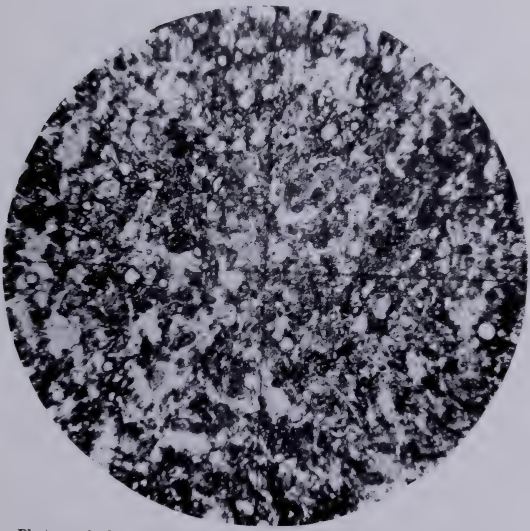
LIMESTONE FROM CURVED STRATA NEAR ELSLACK FREE SCHOOL, CRAVEN.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1. × 20.

GREY LIMESTONE, RAYGILL DELF, LOTHERSDALE.

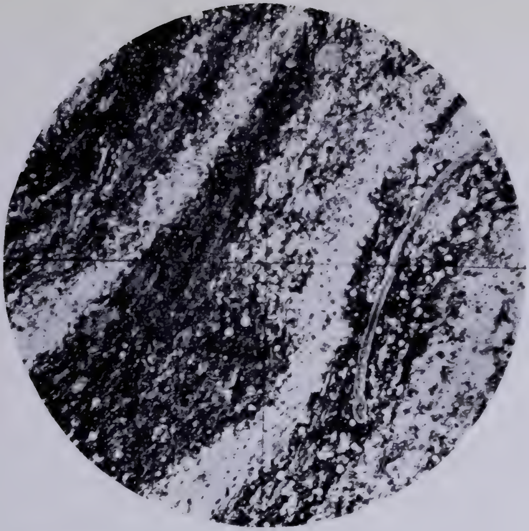


Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2. × 20.

BLACK LIMESTONE, GLEDSTONE KENNELS, CRAVEN.

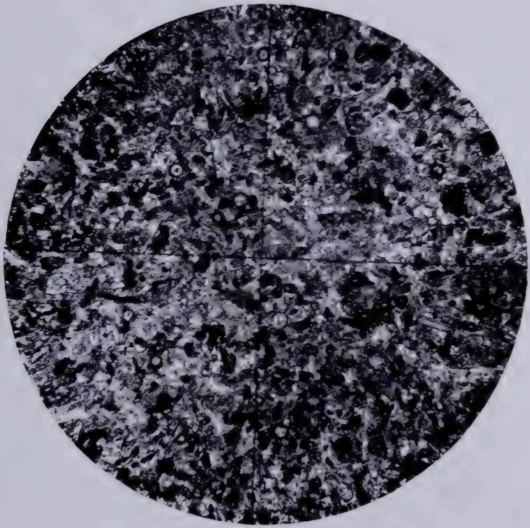
Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLIII.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1. × 12.

CHERT, ELSLACK FREE SCHOOL, CRAVEN.

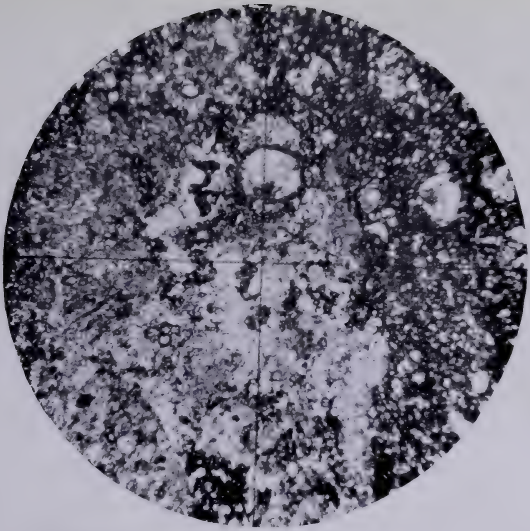


Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2. × 20.

BLUE-BLACK MASSIVE LIMESTONE, UPPER BEDS, HAWSHAW SLACK DELF, LOTHERSDALE.

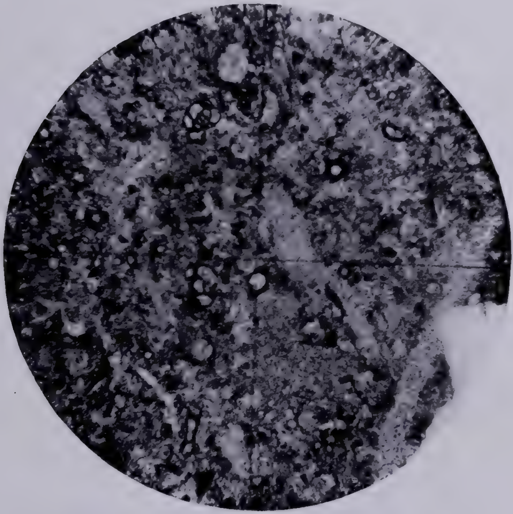
Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLIV.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1. × 20.

LIMESTONE, HALF-MILE FROM PUNCH BOWL, GOLF LINKS QUARRY, NEAR EARBY, CRAVEN.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2. × 20.

BLACK LIMESTONE, WESTERN QUARRY, BROUGHTON FIELDS.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLV.

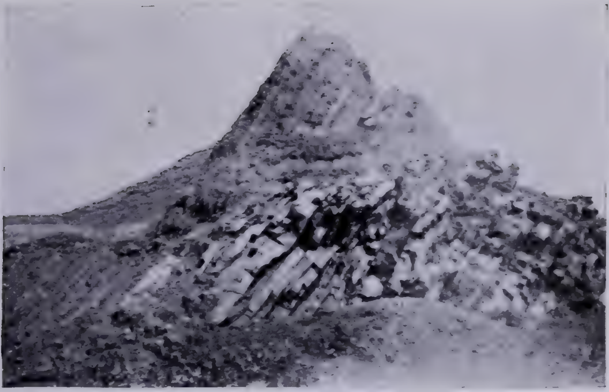


Fig. 1.

GILL ROCK, CRAVEN.

("The strata . . . . . may become tilted into an inclined position." From "Life History of a Mountain," by J. Lomas, F.G.S., A.R.C.S., in "The Nature Book," Vol. I. Price 12s. net. Cassell.)

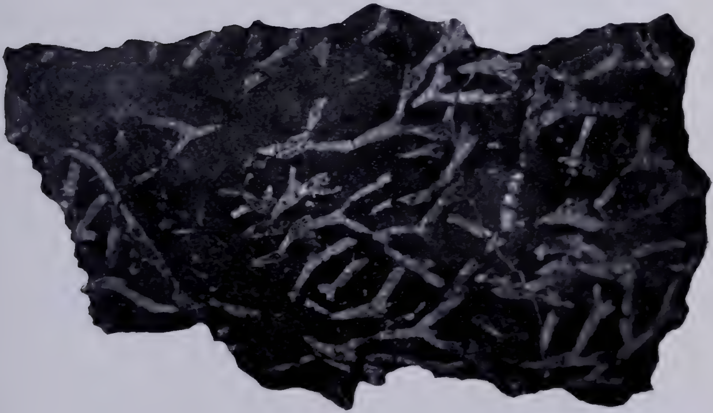


Fig. 2.

SYRINGOPORA RAMULOSA (GOLDFUSS). PROBABLY THE BOTTOM OR "STOLON" PART OF THE COLONY. BROUGHTON FIELDS.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLVI.

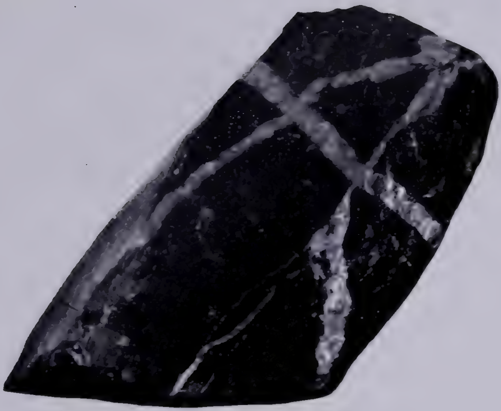


Fig. 1.

BLACK LIMESTONE WITH CALCITE VEINS, STAINTON HOUSE QUARRY, WEST MARTON.

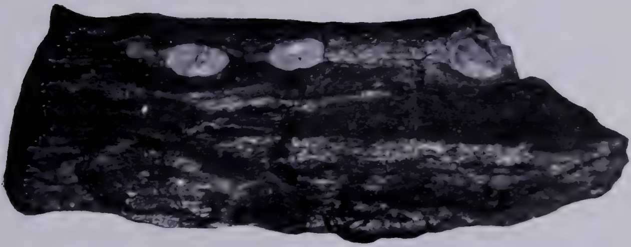
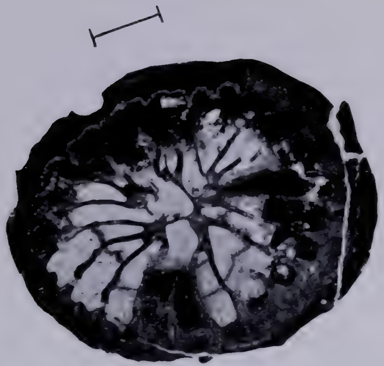


Fig. 2.

FRAGMENT OF CRINOIDAL LIMESTONE CONVERTED INTO CHERT, STAINTON HOUSE QUARRY, WEST MARTON.

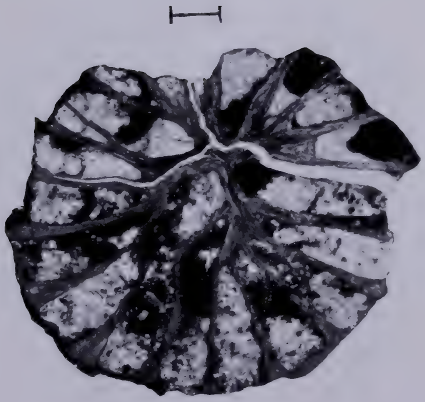
Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLVII.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1.

ZAPHRENTIS OMALIUSI VAR. DENSA, THORNTON QUARRY.

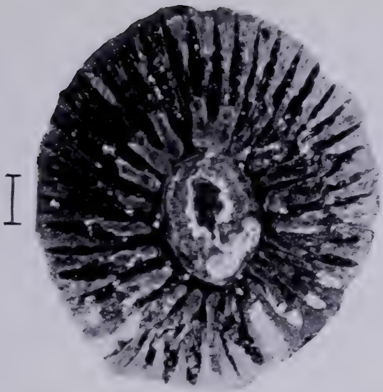


Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2.

ZAPHRENTIS OMALIUSI VAR. AMBIGUA, RAIN HALL QUARRY.

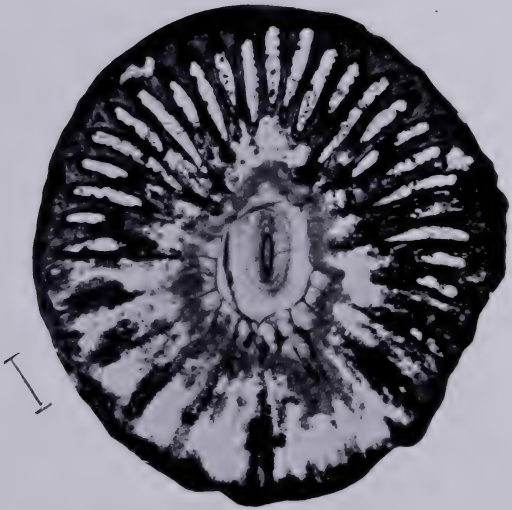
Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLVIII.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 1.

CYATHAXONIA RUSHIANA (VAUGHAN), MARTON SCHOOL.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 2.

CYATHAXONIA SP., KENNELS, WEST MARTON.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate XLIX.

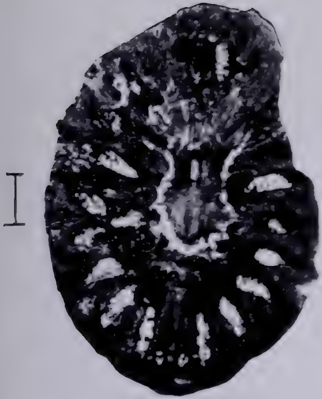


Fig. 1.

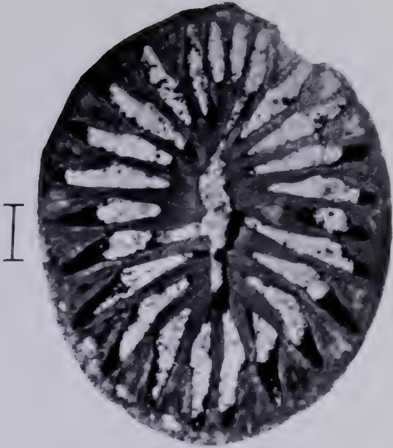
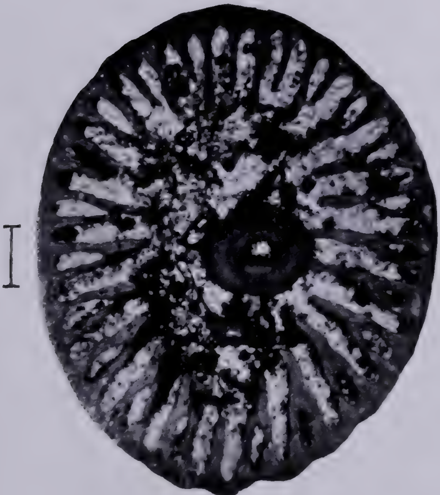


Fig. 2.



Photographed by A. R. Dwerryhouse, Leeds.

Fig. 3.

CYATHAXONIA SP. FROM GLEDSTONE KENNELS—MAY BE A VARIETY OF C. RUSHIANA.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate L.

GASTEROPODS :—

Flemingia spiralis (De Koninck).

Capulus trilobus (Phill.), and others not yet determined.

It will be seen that the faunal assemblage is very similar to that of the Thornton beds, and I can further say that it is quantitatively very similar, those forms which are common in the one being common in the other. These beds thus seem to belong to the same upper Dibunophyllum zone, and I should propose to consider them as the same sub-zone. The beds strike in the same general direction as those of the Thornton anticline, and seem to form the southern limb of a syncline which is apparent at the western end, south of Gledstone Hall, but is buried under drift in the district of Bank Newton.

The beds at Gledstone Kennels may thus be included in this series—see map (23). They represent the northern limb of the syncline. The fossils are absolutely the same as those of Marton School.

THE MARTON-STAINTON SERIES OF EXPOSURES.

The general orientation of these beds was described in my preliminary paper, "The Structure of Some Craven Limestones,"*

The beds are of the same general type as those of the two series already described. The lowest beds are those of Skelda Wood Quarry (24), the highest those in the fields near Stainton House (27) and (28). These are dark massive limestones with frequent shale partings, and in these shales fossils (often much crushed) are obtained. Slickensiding is again very common, and chert is abundant, especially in the upper beds. In Marton Scar and Stainton House Quarries there are the same thin bands of black chert that have been noted at East Marton. There are also the same irregular masses. One piece of chert had an almost square section, the plane of the section coinciding with the bedding plane of the rock. Some masses are irregularly lenticular, while others have somewhat rounded terminations. A sketch of a piece of limestone, about 18 inches by 9 inches, enclosing bands of chert, is given in Fig. 4.

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* Proc. Yorks. Geol. Soc., Vol. XVI., Part I., p. 27.

There is some secondary iron-hydrate, very soft and concretionary. It replaces both crinoidal limestone and the black limestones with cherts.

Many of the bedding planes show the characteristic hummocky surfaces, especially where there are thin and somewhat irregular shale bands with occasional crushed fossils. These shale bands have, in places, the appearance of having been in part squeezed out.

Searching for fossils has proved rather laborious work. Occasionally in the quarrying operations (local road metal), one may see on the fractured surfaces impressions of brachiopods and other fossils. Crinoid stems are more frequent. At one time, in the Marton Scar Quarry (25), I saw quite a number of impressions of *Productus pustulosus* and *P. semireticulatus*. Usually, however, I have not been very fortunate, and I have turned over great quantities of broken road metal with very little result.

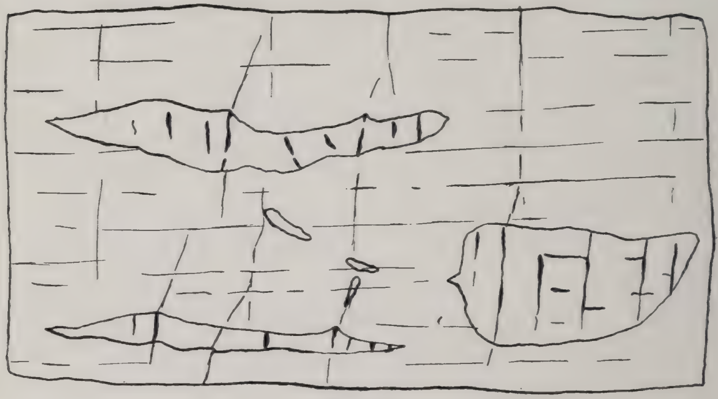

Fig. 4.

SKETCH OF A PIECE OF LIMESTONE 18 INCHES BY NINE INCHES, WITH CHERT BANDS.

There are other ways of obtaining fossils, however. As mentioned in the case of the Marton-Broughton beds, when a quarry has been deserted for years the exposed surfaces often show fossils. The fine calcareous cement, made up of foraminifera and comminuted fragments of corals, enchinodermata, and shells, has been weathered away, and the megascopic fossils are left standing out, as for example in Skelda Quarry, in the older Marton Scar Quarry, and the two near to Stainton House (24), (26), (27), (28).

In the course of time a talus heap of fine débris accumulates at the foot of most of the exposures. By searching in these talus heaps, and in the disintegrated shales which were thrown out during the quarrying operations, it is possible to obtain a few fossils. I have searched many such heaps, and it is from them that I have obtained most of my fossils. The quarry numbered (29) on the map, close to the Nappa road, is much more fossiliferous, and forms quite a good collecting ground.

The fossils I have obtained from this north to south uplift are :—

CORALS :—

Syringopora ramulosa (Goldfuss), and the small variety which I have provisionally named variety *x*.
S. cf. *reticulata.*
? *Cladochonus* sp.
Zaphrentis Omaliusi (Ed. and H.).
Caninia sp.
Michelinia sp.

ECHINODERMATA and POLYZOA.

BRACHIOPODS :—

Rhipidomella Michelini (L'Eveillé).
Athyris planosulcata (Phill.).
A. cf. *glabristria* (Phill.).
Productus pustulosus (a very large form occurs).
P. semireticulatus (Mart.).
P. scabriculus (Mart.).
P. humerosus (Sow.) (Nappa road only).
A giganteid productid, approaching the closely ribbed *P. giganteus* (Mart.) of the Knolls.
Schizophoria resupinata (Mart.).
Chonetes Hardrensis (Phill.).
C. papilionacea. (Phill.).
Orthotetes crenistria (Phill.).

Also several Gasteropods which have not been determined.

These beds apparently belong to the same upper Dibunophyllum zone, and they are clearly succeeded by undoubted Pendleside beds in the district immediately to the north of the area covered by this paper.

NOTES ON SOME OF THE CORALS.

Syringopora ramulosa (Goldfuss). * The commonly occurring form is well represented by the figure in Edwards and Haime.

It occurs abundantly in Thornton Golf Links, Rain Hall, Broughton Fields, and Nappa Road Quarries. Plate XLVI., Fig. 2, represents a specimen from Broughton Fields. Occasionally one may see the very ramulose lower part, with its bifurcating tubes, passing up into a less ramulose form. In this upper part the tubes are much nearer and more regularly spaced. There are comparatively few bifurcations. Some parts of it, except for the rarity of horizontal connecting tubes, might almost be classed as *Syringopora geniculata*.

A small form is found in some of the quarries which is ramulose in its lower part, but has closely packed tubes of reticulate type in its upper part. This seems to be a distinct variety, and I propose, for the present, to speak of it as variety x. The tabulæ, in the specimens I have examined, are farther apart than in the larger normal type.

I have an interesting colony of a *Syringopora* from Clint's Delf. The mass seems to originate from a "growing circle" 3 inches by $2\frac{3}{4}$ inches, and to spread out in a somewhat lob-sided manner into a mass 18 inches long, by 12 inches wide, by 4 inches deep. In the lower part of the colony there is much bifurcating of the tubes, and the appearance is what may be called "sub-ramulose." In the higher part the tubes become roughly parallel and of geniculate type, bending towards each other at the points where the connecting tubes are placed. The tubes have a maximum diameter of, approximately,

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* See Vaughan, Q.J.G.S., Vol. LXI., pp. 267-268.

2 millimetres, and they are about that distance apart. The connecting tubes are not very numerous.*

Zaphrentis Omaliusi (Ed. and H.). Mr. Carruthers has described two varieties of this species, var. *ambigua* and var. *densa* (Plate XLVIII.). The latter he recorded from Thornton Quarry, and from other quarries outside this immediate district. Further search has revealed these varieties in Rain Hall, Gill Rock, Gledstone Kennels, Marton School, and Clint's Delf Quarries. Fine specimens of *ambigua* are found in Rain Hall ; *densa* seems to occur everywhere. Mr. Carruthers has recognised a new variety in some material from Marton School ; this is as yet unnamed. As mentioned in the earlier part of the paper, this species swarms in Thornton Quarry and I have handled hundreds of specimens. I have had a great many cut down, and Dr. Vaughan and Mr. Carruthers have kindly examined some for me. From the examination of a great number, and assisted by the notes supplied by the above-named experts, I should say that the variety *densa* is much more common than the normal type, and that *ambigua* is not nearly so common. There are gradational forms, as mentioned by Mr. Carruthers,† and these occur in plenty. Densiphyllid forms of var. *densa* are common.

Caninia cornucopiæ (Michelin) occurs in several exposures, and a remarkable feature is the occurrence of the true species, as well as the mutation d.

A new species of *Caninia*, not yet described, was found in Marton School Quarry.

Cyathaxonia Rushiana (Vaughan) (Plate XLIX., Fig. 1) is quite common, especially in the Marton beds. The small septal protuberances described by Dr. Vaughan‡ are noticeable.

A *Cyathaxonia* from Marton School is probably a new species, but more material must be found before description is possible.

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* I have examined a great many specimens of reticulate and geniculate *Syringopora* and I find that the number of connecting tubes is a very variable character. Milne Edwards and Hanne lay stress on this character in the discrimination of *reticulata* and *geniculata*.

† See Bibliography, p. 371. Carruthers.

‡ Q.J.G.S., Vol. LXIV., p. 460.

The association of the corals is somewhat interesting. I give that of three quarries :—

RAIN HALL :—

Zaphrentis Omaliusi, var. *densa.*
,, ,, ,, *ambigua.*
Caninia cornucopiæ.
,, ,, mutation d.
Cyathaxonia Rushiana.
Michelinia sp.
Syringopora ramulosa.

MARTON SCHOOL :—

Zaphrentis Omaliusi, var. *densa.*
Caninia cornucopiæ ? mut. d.
Caninia sp. nov.
Cyathaxonia Rushiana.
Cyathaxonia sp. nov.
Michelinia sp.
Syringopora sp.

GLEDSTONE KENNELS :—

Zaphrentis Omaliusi, var. *densa.*
,, ,, ,, *ambigua.*
Caninia cornucopiæ ? mut. d.
Cyathaxonia Rushiana.
Syringopora sp.

It is remarkable that there are few specimens of the larger corals to be found. These seem to be fairly plentiful in the vicinity, for at Coniston Cold, Bell Busk, and Swinden I have obtained them in plenty. In addition to occasional occurrences of *Michelinia* and the ubiquitous *Syringopora*, the small Zaphrentid-like corals seem to be almost the only forms.

I wish to sincerely thank several of the Carboniferous experts for advice and help very freely given.

Mrs. Longstaff kindly identified the common Thornton gasteropod for me.

Dr. Vaughan has kindly named brachiopods and corals submitted to him.

Dr. Wheelton Hind has been most patient and has helped me with many suggestions ; he has also identified many brachiopods and the *Capulus trilobus* from Marton School.

Mr. R. G. Carruthers has, without a murmur, checked many specimens of *Zaphrentis*, *Cyathaxonia*, and *Caninia*. He has also furnished the sections of *Cyathaxonia Rushiana*.

I hope Dr. Dwerryhouse will allow me to express my sincere thanks to him for all the help he has given me in this and previous papers, in photographing micro slides, in the production of the maps, and in criticisms and advice.

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CARRUTHERS, R. G. "A Revision of some Carboniferous Corals," Geol. Mag., New Series, Decade V., Vol. V., January, February, and April, 1908.

A General Bibliography of other literature was given in the author's general paper, Proc. Yorks. Geol. Soc., Vol. XVI., pp. 28-30.

THE GLACIATION OF NORTH CLEVELAND.

BY FRANK ELGEE.

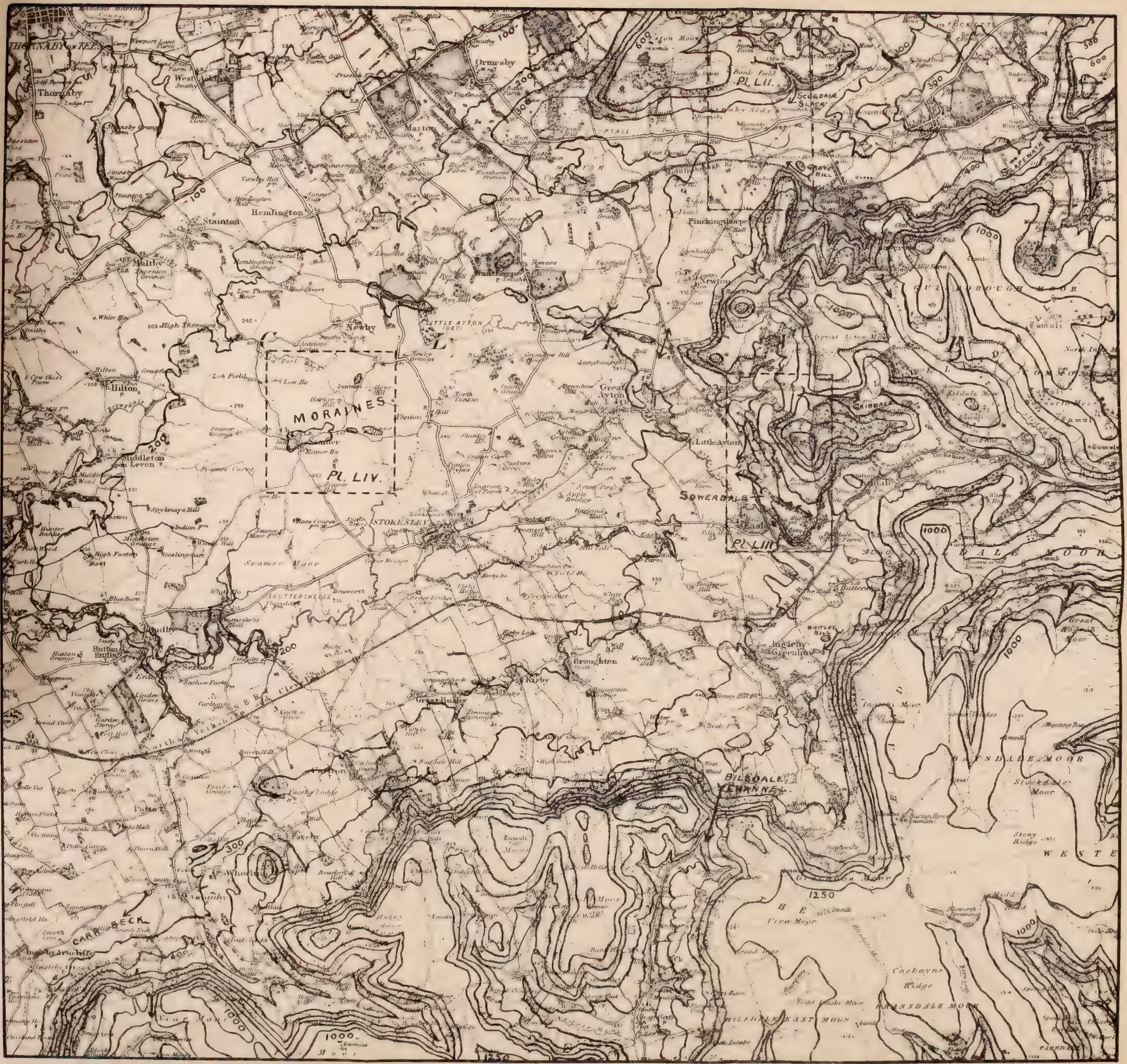
(*Read 26th September*, 1908. *Manuscript received 5th December*, 1908.)

Thanks to the great work of Professor Kendall in the Cleveland area, glacial geologists are now furnished with a key which will enable them to trace the history of the decline of the glaciers which debouched on to the plains of England during the Ice Age. Even in the area which he has made classic, work still remains to be done in deciphering the records of the various stages in the retreat of the ice from its position at maximum extension until it finally vanished from the district. The following notes, therefore, deal with the glacial phenomena produced during the retreat of the ice in North-west Cleveland, and embrace the Upleatham and Eston Outliers, the Guisborough Valley, and the Cleveland Plain of Stokesley.

The phenomena to be discussed may be conveniently divided into three groups, corresponding chronologically to three positions of the ice margin, viz. :—

1. Phenomena at the period of maximum extension.
2. Phenomena at the foot of the Cleveland Hills during the retreat.
3. Phenomena connected with a halt of the ice on the Plain of Stokesley.

The phenomena at the period of maximum extension have been fully elucidated by Professor Kendall, and are mentioned here so that what follows may be fully understood. There can be little question that he has conclusively established the existence in Cleveland, during the later phases of the Ice Age, of a large glacier that had passed over a part of the Cheviot Hills. The occurrence of Cheviot erratics, of striæ, and, above all, of the lake phenomena, yield evidence in support of this contention. In the area under consideration, all the phenomena go to verify the presence of this glacier, and it may be remarked



Proc. Yorks. Geol. Soc., Vol. XVI., Plate LI.

Scale: 1 inch to a mile

GENERAL MAP OF THE DISTRICT DESCRIBED IN MR. ELGEE'S PAPER.

(The portions enclosed by broken lines are reproduced on a larger scale in Plates LII., LIII., and LIV.)

Reproduced from the Ordnance Survey with the Sanction of the Controller of H.M. Stationery Office.

at the outset that the occurrence of large blocks of Augite Andesite from the Cleveland Dyke, to the south of its outcrop, affords further proof of a northerly ice stream. An exceptionally large boulder of this rock stands in a field just south of the Dyke at Stainton. At the period of maximum extension, the Cheviot Glacier swept right into the angle of the Cleveland escarpment, several small lakes being held up along its slopes, and overflows existed at Gribdale Gate, the head of Bilsdale, Holy Well Gill, and Scarth Nick.* (See Map, Plate LI.)

These overflows were abandoned with a very slight shrinkage of the ice margin, and the impounded drainage would now escape along the lower slopes of the Cleveland Hills, but only one stream appears to have left any traces of the subsequent course of the water. This, the Gribdale Gate overflow, ceased to operate at a level of 747 feet, and therefore, the lake impounded in the hollow of the hills between Roseberry Topping and Easby Moor must have escaped either to the north or to the south. The overflow at the head of Bousdale, half a mile north of Roseberry Topping, discovered by Mr. Kendall at an elevation of 675 feet, indicates a westerly flow, and in all probability this drainage swept round the hills to Kildale, and was joined by the Gribdale Gate waters. No channels are met with proving this until we arrive at the 575 foot contour, at Castle Hill, Easby, where a small valley exists which will be described later.

A further retreat of the ice permitted the extra-morainic drainage to travel at a still lower level. To this stage belongs the deviation of Boosbeck, through the great gorge at Slapewath, which cuts from 600 feet down to 425 feet or thereabouts. In alignment with this rock gorge is a channel at the foot of Bousdale Hill, near Pinchingthorpe, with a great bank of drift (Grove Hill) in front of it, and cutting, at its outfall near Lowcross House, the 325 foot contour. Still further to the west, at Langbaurgh, a well-defined overflow crosses the Cleveland Dyke, and is certainly in alignment with the Grove Hill channel, since the altitude at which it commenced to be eroded is 325 feet, the level of the floor of the Grove Hill Valley. The Langbaurgh overflow presents some features of interest. Just to the west of, and parallel to it, is a slight trench in the ridge at 325 feet, over which the glacier appears to have readvanced. The overflowing waters then commenced the gap through which the Tame flows, and cut down to 275 feet. At the intake of the channel, on the north side of the Dyke, is a mound of drift at an altitude of 300 feet, in front of which the overflow has clearly taken place. The present stream, the Tame, which well merits its name, cannot have cut the gap, as further to the west is lower country at 275 feet, a clear case of an ice barrier.*

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* Kendall, Q.J.G.S., Vol. 48, pp. 513–519.

The fall of these valleys is in consonance with Mr. Kendall's observations regarding the overflow at Bushy Dale Wood, on the eastern side of the Boosbeck Valley, " which shows that the main overflow to which it was related was at a low level, and I feel assured that it was into the Vale of York." To summarise the altitudes : Bushy Dale, 600 feet ; Slapewath, 600–425 feet ; Grove Hill, 450–325 feet ; Langbaurgh, 325–275 feet.

A retreat of the ice, when Slapewath had been cut down to about 425 feet, enabled the waters of Boosbeck to flow to the sea at Saltburn, and this explains the fact that no dry valleys have been eroded on the northern slopes of Airy Hill, for when the ice-front was standing on that hillside the drainage was travelling down the Guisborough Valley.

A series of channels occurs at the foot of the Cleveland Hills which belongs to an earlier stage than the preceding, and which may, judging from the altitudes, have carried the extra-morainic drainage from the Boosbeck Valley for a brief period. These valleys, however, do not seem to form an aligned sequence, but rather appear to be due to lobes of ice standing on or behind drift mounds, and allowing the drainage of the slopes to sweep between them and the hill sides. The Grove Hill channel is one of these (Plate LII.). Near Great Ayton Station we find a great mound of drift at 450 feet, with a channel between it and the steep hillside. It is nearly 50 feet deep and falls southwards (Plate LIII.).

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* The Tame is mostly artificial, consisting of drainage channels for the formerly swampy Guisborough Valley.

The next extra-morainic channel of this kind is one at the foot of Turkey Nab, near Battersby. This, Whitley Hill, has precisely the same characters as the preceding, but probably belongs to a slightly earlier stage, since it is at 500 feet cutting down to 475 feet. Extremely significant is the fact that no overflows of this sequence and the Boosbeck sequence occur between Ayton and Battersby. Yet there must have been a free course for the water round the Castle Hill at Easby, or else it would have gone into Kildale, for which, however, there is no evidence. On the contrary, there must have been an outflow from that valley, of which there is no trace left, for reasons presently to be assigned.

Along the main slopes of the Cleveland Hills, as far as Carlton, no traces of overflows have been detected, yet a considerable body of water must have been held up. At Busby Hall, however, an overflow, though very shallow, crosses the spur there at 425 feet ; but north-west of Whorl Hill is a splendid example of this series of channels, cutting from 300–250 feet. It falls to the east, however, and may have been produced at a later stage by a temporary flow of Swainby Beck in that direction. To the south-west of the village, and in front of the great moraines blocking up the entrance to Scugdale, is a shallow, wide trench in the drift, which looks like a glacial drainage channel, but it may owe its origin to Carr Beck, a fact rendered more probable by the course of Swainby Beck, which just crosses the low watershed between these two channels. Its so doing excludes the possibility of its having travelled at any time along the Carr Beck Valley, which must have happened if this had really been an extra-morainic channel.

I have not yet been able to discover any other signs of the Vale of York drainage between the foot of the hills and the course of the Leven, north of which the ice halted for a considerable time and deposited great moraines.

We have now to consider a rather peculiar problem. At the entrance to Kildale, as already remarked, there exist no overflows indicating a line of drainage into the Vale of York.

On the contrary, whatever extra-morainic valleys occur there, prove a flow towards the Guisborough Valley in another direction altogether.

At the entrance to Kildale a low spur, called Castle Hill, projects from the slopes of Easby Moor at an extreme elevation of 600 feet (Plate LIII.). The drift here appears to fill up a small preglacial valley or depression, which exists between the main hill and now forms Sowerdale, and a small outlier of the Sandy Series of the Lias at Burrow Greens Wood, round the very base of which flows the River Leven. Across this spur, overflows, both into and out of Kildale, have certainly taken place. a fact noted by the late Rev. J. Hawell,* who says, "I have recently discovered that there was almost certainly an overflow from the Eskdale Lake at one time into Sowerdale. Anyone looking at Sowerdale will be able to see that the denudation of it cannot have been entirely due to the insignificant stream which now percolates through it."

An examination of the ground showed some peculiar features. Sowerdale itself is about half a mile long and cuts right across the spur, and is divisable into two portions where the path from Copper Hall to High Farm on Castle Hill crosses it. Here is a trench at 575 feet, about 25 feet deep and quite streamless. It falls to the south-east, where it opens on to the steep slopes above the Leven. In the lower portion a spring has produced a small runlet of water, but this has evidently not been the cause of the valley, which is clearly an overflow and seems to have drained the Gribdale Gate area (possibly with the addition of the overflow from the Boosbeck Valley for a brief period) into Kildale, and it is worthy of note that the altitude is almost the same as that of the West Bank watershed (dividing Kildale from Eskdale), beneath the peat, viz., between 580 and 550 feet. The exact level of this watershed is difficult to ascertain with precision, but if we accept the above channel as indicating a flow into Kildale and Eskdale, then the altitude of its floor will give us the elevation of the rocky bottom at West Bank, at the close of the drainage eastwards, that is to say 550 feet.

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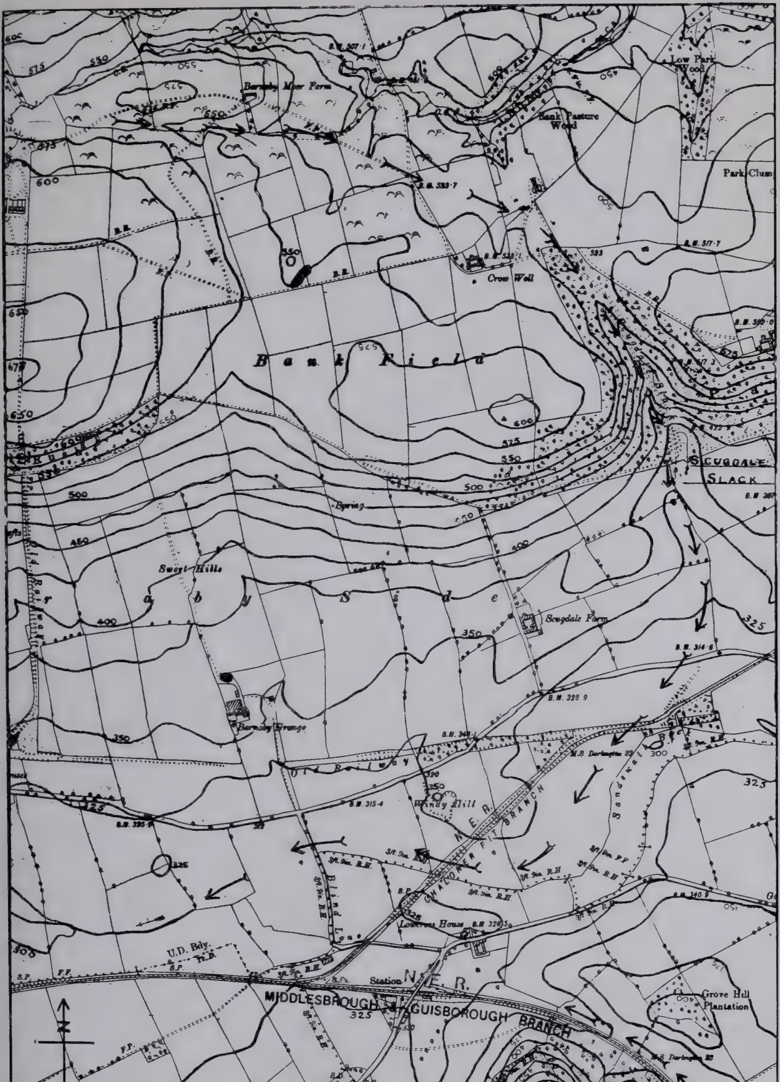
*Proceedings of the Cleveland Field Club, Vol. II., p. 25.

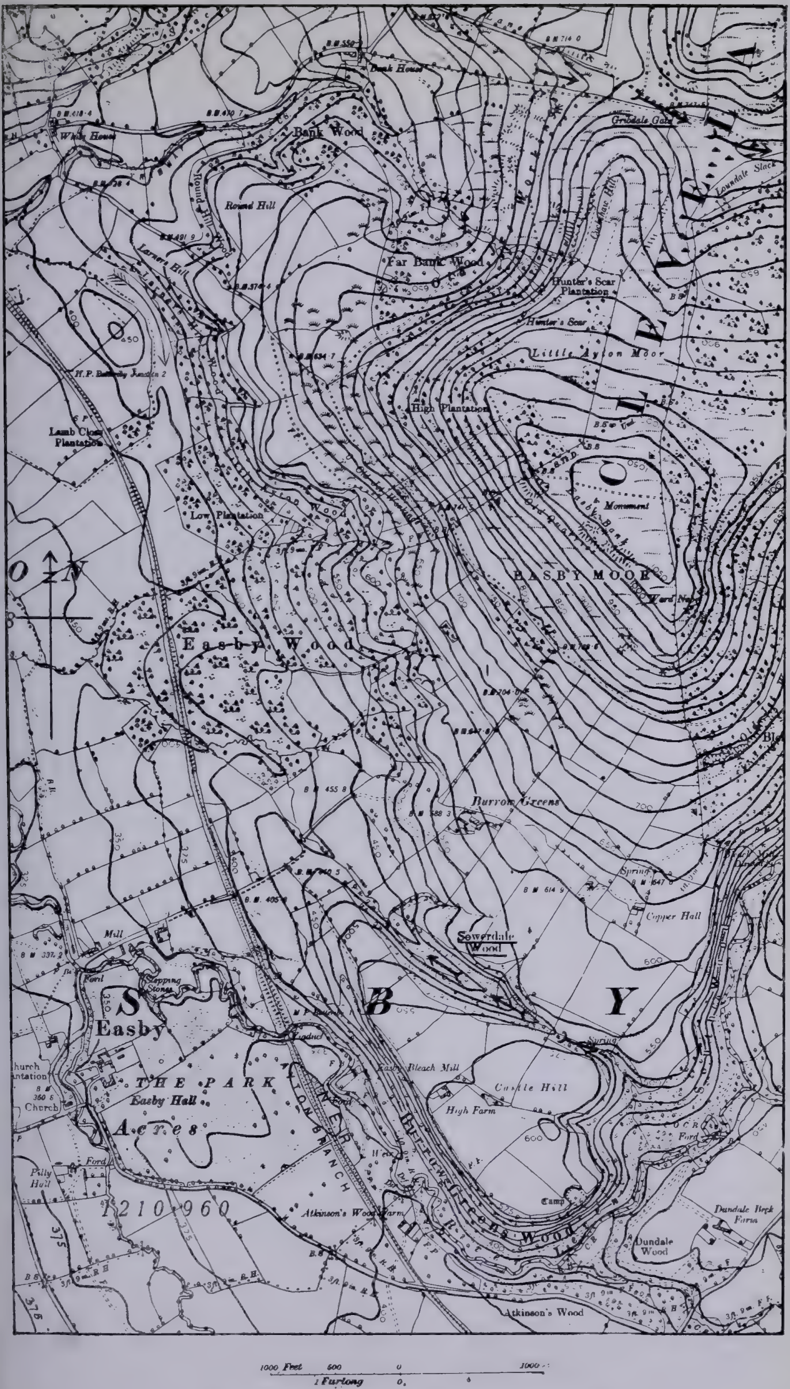


SCUGDALE SLACK AND GROVE HILL OVERFLOWS.

Reduced from the Ordnance Survey.

(With the sanction of the Controller of H.M. Stationery Office.)

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LII.

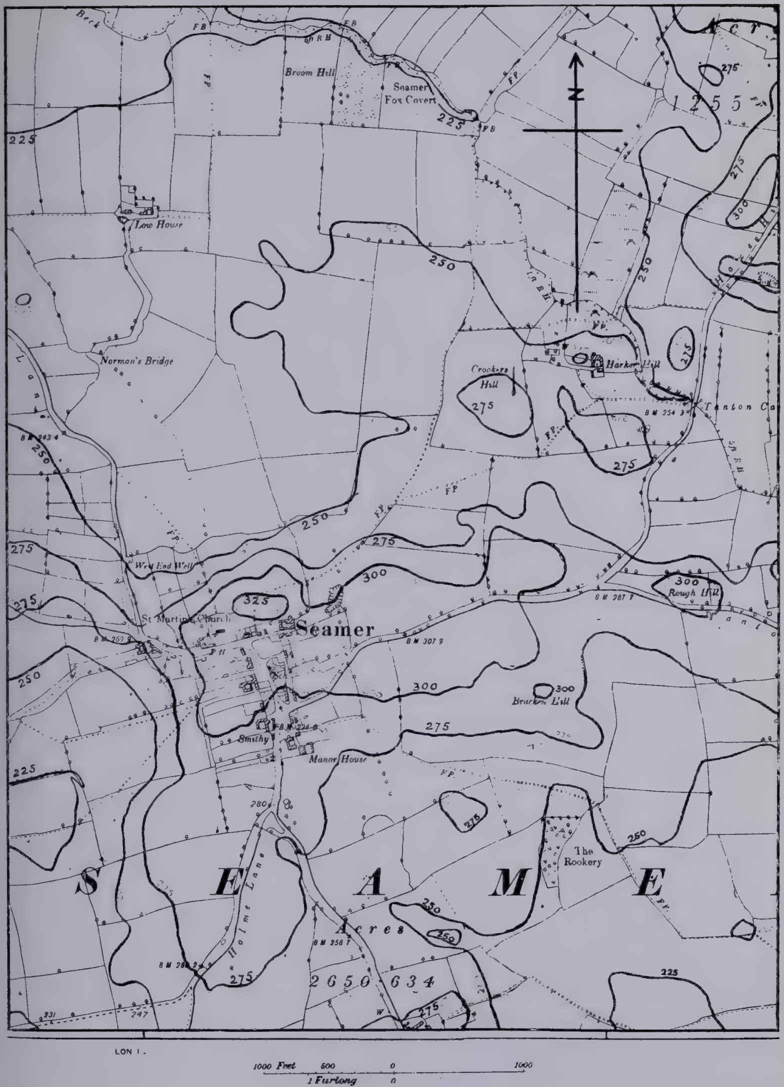


SOWERDALE AND THE COURSE OF THE LEVEN.

Reduced from the Ordnance Survey.

(With the sanction of the Controller of H.M. Stationery Office.)

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LIII.



LON 1.

NEIGHBOURHOOD OF SEAMER, NEAR STOKESLEY.

Reduced from the Ordnance Survey.
(With the sanction of the Controller of H.M. Stationery Office.)

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LIV.

Sowerdale falls to the north-west and is a valley about 150 yards wide at the top, and about 100 feet deep, cutting from 550 to 450 feet. It has very steep sides, apparently composed of drift, and stiff clay is exposed by a very small stream, not 12 inches wide, on its floor. I do not think that this insignificant stream can be regarded as the agent which produced Sowerdale. Elsewhere in Cleveland much larger streams have eroded much smaller channels in the drift, and moreover, the Sowerdale rivulet is practically non-existent in the summer. The upper part of Sowerdale has a very steep ascent to the watershed, the floor of the south-easterly flowing channel above-mentioned. Here, therefore, on the same spur we have two overflows in opposite directions, and one on a very much larger scale than the other.

At first sight it would appear that after Lake Kildale had ceased to drain into Eskdale, it overflowed across the Easby spur and thus excavated Sowerdale. This was the opinion of Mr. Hawell, and he further adds :—"This water was able to flow out at a lower level between the ice mass and what is now Easby Castle Hill. As the ice gradually shrank, the outflow came to be at a progressively lower level, but still hugged the Castle Hill, ... and so when the ice had quite gone, the Leven had cut its channel close under the hill."* This explanation certainly fits the facts and explains the parallel trend of Sowerdale and the River Leven, the latter of which hugs the Castle Hill slope in a most remarkable way. But if the Cheviot ice was the agent in causing these phenomena, where was the escape for the overflowing waters to the north-west, an area covered by the glacier itself ? The overflows could not have travelled round the foot of the hills to the Boosbeck Valley, since the overflows in that area indicate drainage westwards below 600 feet. To reconcile these apparent contradictions is difficult. The overflowing waters may have escaped over or under the ice, but that two opposite drainage lines could be in operation at the same time, along the same hill slopes, one of which escaped under or over the ice and the other did not, appears, to say the least, highly improbable.

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* Op. cit.

Looking for an outlet in a northerly direction, the Sowerdale overflow could only have escaped into the Guisborough Valley at a time when the Slapewath overflow had ceased to operate and when a free outlet allowed the drainage to escape to the sea at Saltburn. All the phenomena of Skelton Beck are well below 350 feet, and if the ice readvanced and blocked up Kildale again, *after the Vale of York drainage had ceased*, we should have had the impounded drainage cutting across Castle Hill and forming Sowerdale. At a later stage the overflow, now the Leven, escaped in the manner described by Mr. Hawell, since at the foot of Easby Wood it persistently refuses to take a more direct and much lower course towards the south-east, showing the presence of an ice barrier. Hence the probability is that Kildale may have been blocked up for a brief period by a readvance after the coast as far north as Saltburn was free from ice.*

This readvance would also account for the fact that no signs are left of any channels out of Kildale in alignment with the Vale of York drainage system. Mr. Kendall expressly states :—"The ice front must have stood across the Boosbeck Valley until the Slapewath Gorge was lowered below the level of the drift barrier across Boosbeck—that is to say, below 425 O.D. From this clue it is possible to define some of the further course of the stream and consequently of the ice front. It will be remembered that the overflow channel into Eskdale by way of Kildale is at an altitude of 580 feet, therefore it is quite certain that there must have been a line of drainage open into the Vale of York (p. 566)." Now the sequence of overflows connected with the lower stages of Slapewath proves that this line of drainage existed. But where are the traces of the drainage out of Kildale corresponding to this state of affairs ? The valley of Sowerdale and the course of the Leven indicate no flow into the Vale of York. A readvance would, however, obliterate all traces of the Vale of York drainage from Kildale, and explain, I think, the very curious phenomena of the Castle Hill.

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* With regard to Sowerdale, Professor Kendall has kindly furnished me with the following note :—" I am very doubtful whether the Sowerdale Valley could be regarded as a lake overflow. The arrangement of the contours does not suggest erosion by a large stream, for it seems too wide and too steep at the head. It is of the type of Bridle Gill (north of Roseberry Common). A stream that could cut a valley of such breadth would have eroded its floor in a broader notch, and have obliterated all signs of the flow towards Kildale. Experience gained in the last two years has made me suspicious of cases of apparent flow in opposite directions through the same channel. It is easier to assume that a transverse watershed or "corrom" has been produced by inflow by a lateral stream, or by some similar means." Even if we reject Sowerdale as an overflow, the anomalous course of the Leven has still to be explained, so I have let the above-given explanation of its origin stand.

I have looked for traces of the northward flow from Kildale along the Guisborough Valley, but no channels were found. The advanced position of the ice front near Ayton must have prevented the Sowerdale and Leven flows from passing through the Dyke at Langbaurgh, as the channel there, if free, would at once have been utilised. Further east along the ridge of the Dyke is a low col at 350 feet, over which extra-morainic drainage must have passed, for a well-defined though small channel occurs here, but the fall of it is so slight that it is quite impossible to say in which direction the drainage has really gone. It must be admitted, however, that the non-occurrence of definite overflows in the Guisborough Valley in alignment with Sowerdale is against the explanation given of the origin of that valley.

Turning now to the Plain of Cleveland, I have to remark that after the phenomena above described had been produced, the ice stood for a long time for about a mile to the north of Stokesley, and a splendid series of moraines and gravel mounds was deposited. The most southerly and most striking of these moraines, evidently marking a halt in the retreat of the ice, runs from near Hilton to the east of Seamer (Plate LIV.). The road from Hilton to Seamer follows the trend of the moraine which, as might be expected, runs in an east and west line. It takes the form of a series of mounds of gravel and sand separated by slight hollows. These mounds have received local names, and, running from west to east, they are :—Boy Hill, 300 feet ; the Kirk Bank, at Seamer, 325 feet ; Rough Hill, 300 feet ; and Hunter Hill, 300 feet. To the south they slope gradually down to Stokesley, but on the north they have a very steep descent to 250 feet, especially north of Seamer, where the ground is very flat and peat-filled. The Kirk Bank is about 75 feet high, and near the church is an old gravel pit so grassed over that no clear section is visible. A large slab of Old Red Conglomerate and boulders of Cheviot Porphyrite were observed near the top of the pit, whilst rabbit scratchings revealed fine sand.

The flat peaty area north of Seamer extends a little eastwards, where, to the north of Rough and Hunter Hills, three parallel series of mounds can be traced. The first comprises Crooker's and Harker Hills, both at 275 feet. In the latter is a sand pit which yielded a clear section. Below the subsoil occurs a gravelly stratum about one foot thick, with waterworn pebbles and boulders of Porphyrite, Carboniferous and Magnesian Limestones, and Borrowdale Andesite. This gravel passes into ruddy sandy clay with bits of coal, below which is a great mass of sand containing very few, if any, boulders, some broken shell fragments, and a large quantity of coal fragments. In fact, this sand so closely resembles the sea sand with coal on the shore between Redcar and Saltburn, that one is inclined to think that similar coaly sand has been conveyed to the area under discussion by the ancient ice.

Further north, a ridge known as How Hill probably marks another stage of retreat, and stands at 300 feet. Near an old tumulus is a sand pit, but the section is now nearly grassed over. Here finely bedded coaly sand could be seen near the surface in one place, whilst in another was gravel passing down into very coaly sand. The bedding was horizontal, coinciding with the flat top of the ridge. A large block of Carboniferous Sandstone was noted here.

Yet another section occurs in a fourth ridge of drift between How Hill and Spring Well Hill, where gravel at the top can be observed dipping sharply to the east, corresponding with the slope of the surface. The gravel here is ruddy and contains much clay. Many boulders were observed, and they proved how inextricably mixed up the two series of erratics are. A large block of Shap Granite was found alongside Cheviot Porphyrites and Magnesian Limestone, Augite Andesite, and Criffel Granite ; whilst on the floor of the quarry were two large boulders of Carboniferous Limestone, one of them showing weathered fossils. Liassic fossils also occurred here, although the drift is mapped as lying upon the Triassic Rocks. The fossils were Lower Lias forms—*Gryphæa arcuata*, *Ammonites angulatus*, and an indeterminable *Pecten*. They seem to show that the Cheviot ice moved in a south-westerly direction on to the Cleveland Hills at the western end.

At Newby and to the north as far as Marton and Tollesby, the surface is covered with Boulder Clay, which often assumes the form of ridges and mounds, though not on such a striking scale as those just described. In the stream sides a bed of sand occurs in the clay, dividing it into two layers, and near Marton I have found in it striated Magnesian Limestone, Lower Lias fossils and clay ironstone concretions. I do not think that these sands can be correlated with those near Seamer, since the latter have no Boulder Clay above them. The so-called Upper Boulder Clay terminates in a long ridge running from Marton towards Stainton, with a long strip of sand and gravel running along its slopes as far as the village of Eston.

Probably during the deposition of the Stokesley moraines the dry channels on Eston Hill (described in a paper to "The Naturalist," August, 1906) were being eroded, since both features indicate the last considerable halt of the ice in North Cleveland. The ice front would by no means be straight, owing to the form it would assume after contact with the great embayment of the Jurassic escarpment at Greenhow Botton. The drainage from Scugdale Slack, on the Eston outlier (Plate LII.), swept round to the south-westwards along the Guisborough Valley, and a shallow channel can be traced as far as the Langbaurgh overflow. It seems probable that though some of the waters escaped through the gap, the rest simply spread over the drift-covered floor.

The results obtained by this survey of the glaciation of North Cleveland may now be summarised as follows :—

1.—The period of maximum extension when the Bold Venture moraine and drift pebbles at 1,000 feet on Newton Moor were deposited, and Holy Well Gill was eroded. (Kendall.)

2.—Period when Gribdale Gate, the Bilsdale overflow, and Scarth Nick were in operation. (Kendall.)

3.—Period when the Bousdale overflow at 675 feet was formed. (Kendall.)

4.—Period of extra-morainic drainage at the foot of the Cleveland Hills during the earlier stages of Slapewath.

5.—Final stages of the Slapewath and Langbaurgh overflows.

6.—Period of readvance at Kildale leading to the formation of Sowerdale and the anomalous course of the Leven.

7.—Period when Scugdale Slack and the Stokesley moraines originated.

SOME EFFECTS OF THE STORM OF JUNE 3RD, 1908, ON BARDEN FELL.

BY ALBERT GILLIGAN, B.Sc.

(*Read* 12*th November*, 1908. *MS. received* 30*th November*, 1908.)

Storms of more or less violence occurred in many parts of the British Isles on June 3rd, 1908. The West of Yorkshire seems to have been unfortunate in being the neighbourhood where the greatest downpour of rain took place, and consequently suffered more destruction than any other district. The stretch of country affected by the storm extends from Airedale to Swaledale, embracing in its path four watersheds. Much havoc was wrought throughout the whole area, but the special district with which it is proposed to deal is that of Barden Fell. The highest point of the hill, near the Upper Barden Reservoir, is 1,661 feet above sea level. The hill is drained normally by a number of becks, which flow radially from its summit, the chief of which are Barden Beck and Gill Beck on the east; Loburn Gill and Moor Beck, which join to form Embsay Beck, on the south; while on the west there are Fell Gill, Waterfall Gill, and Red Gill, tributaries of Eller Beck (see Map, Fig. 1).

These streams all run down scarp slopes of the Kinderscout Grit, of which the hill is composed, and have in consequence deep narrow channels, with many waterfalls, where they have encountered the beds of shale which are interbedded with the grit.

I visited the district in the neighbourhood of Burnsall a few days after the storm, and explored the fell side, which is in the occupation of Mr. Thompson, Wood End Farm. In the field below the main road from Bolton Abbey to Burnsall deep trenches had been cut, and some of the solid grit removed. The field was strewn with blocks of grit, and the wall bounding the field on the lower side had been breached in two places (Plate LV., Fig. 1). Following the track of the torrent up the fell side, it was found that the main road had been ploughed

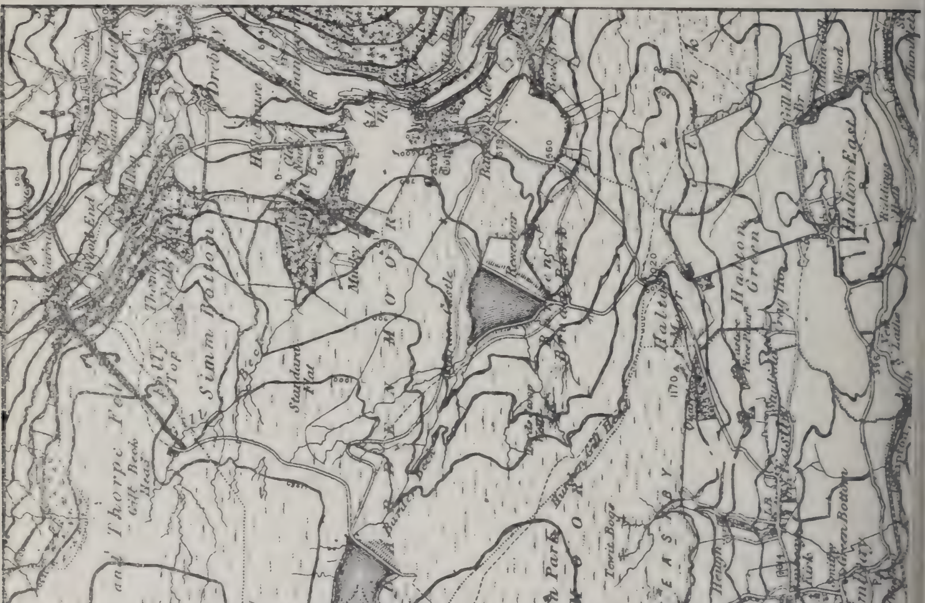

Fig. 1.

MAP OF PORTION OF THE AREA AFFECTED BY THE STORM. REPRODUCED FROM THE 1 INCH ORDNANCE MAP.

(With the sanction of the Controller of H.M. Stationery Office.)

up to a depth of six feet, and the walls on either side thrown down, leaving gaps about twenty feet wide. The height at which the water had stood at the fell side of the top wall was easily traceable by reason of the bracken and grass infilling the chinks. This height varied from eighteen inches to three feet six inches, according to the lie of the ground. The water crossed the road at a point where the ground rises to a crest in the line of the new channel. In this new channel was found remarkable evidence of the cutting power of a mountain torrent. Careful measurements showed that in many places the solid grit had been removed to a depth of twenty feet, while the greatest width was twelve feet. The deepest holes were always found succeeding a place where the water had been imprisoned in a narrow channel, and the material scooped out of the hole has been piled up on the lower side to form a boulder bar.

"Scape-colks" similar in their mode of origin, i.e., constriction of the water channel, have been described by Suess* as occurring in the bed of the Danube during the construction of dams for the purpose of diverting the river. Much of the rock in this part of the channel is crushed, as by faulting, and a vein was found at one part, but a search failed to reveal any metalliferous ore, though on the other side of the valley of the Wharfe the veins in the limestone bear galena, which has long been worked. It seemed at first as if the course of the stream had been determined by a pre-existing channel along a line of fault, but I was assured by those in the neighbourhood who knew the ground thoroughly that no channel had existed there prior to this storm.

Another interesting feature, which was noticed both in this channel and at most other places round the fell, was that a stiff boulder clay, containing limestone pebbles, which covered the ground, had offered a powerful resistance to the cutting action of the current, and had preserved the underlying rock. The wall separating this field from the rock-strewn fell above had, in common with others, been breached, and afforded evidence of previous storms, not so violent perhaps as the present one, but nevertheless bringing down much material from the higher part of the fell. The old foundations of the wall could be seen six feet below the present level of the ground, and stratified gravel, alternating with beds of peaty mud and angular pieces of grit, were exposed where the wall had been washed away (Plate LV., Fig. 2). This wall had fortunately determined the course of one of the tributary streams along the top of Thompson's Folly Plantation, or the farm which lies directly below might have been swept away. In the channel cut by this tributary stream evidence of the forces bringing about the folding and faulting of the whole district could be seen in the beds forming an unsymmetrical anticline, which had passed over into a reversed fault on the other side of the channel.

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* Suess, "The Face of the Earth," Vol. II., p. 343.

Striking north-west across the fell two old channels were found, now quite dry and unaffected by the storm, which were probably the drainage channels of some previous storm, and helping to confirm the observations made regarding the stratified deposits near the wall. Another channel only fifty yards further on was one of the main drainage channels of the recent storm. The amount of material cut out of its bed was enormous, and has been spread out in a fan some distance below. In nearly all cases the cutting in the smaller channels branching from the larger ones commenced quite suddenly, due no doubt to the cutting back of the waterfalls formed by the rapid deepening of the main channels, each of the waterfalls having the usual boulder bar. A portion of one of these new channels is shown in Plate LVI., Fig. 1.

An old cart-road leading up to a quarry on the fell side had during the first part of the storm formed an easy escape for the water, but as the volume increased the water could not follow the windings of the road, and burst through the sides at the sharp turns, just as rivers cut a shorter channel and leave the " ox-bow " channels on their sides as records of their former courses.

To the north of this road a fault which runs south-west to north-east, and throws the Millstone Grit against the Pendlesides, has been well exposed, and some interesting points which need more careful study have been disclosed along this fault line. It seemed at first nothing more than a normal fault, but an examination of the shales in the grit showed evidence of much crumpling, in one place, at least, the beds being vertical. The grit along the line of fault is much crushed, and has wisps of Pendleside shale caught up in it. Furthermore, the Pendlesides here show beautiful slickensiding along horizontal planes. Confirmation of what appears to be thrusting is found again lower down the fell side, where the beds are inclined 45° in the direction N. 60° W., and appear to have been packed up over the beds below, which are nearly horizontal. The direction of dip here is almost at right angles to the dip found near the fault in the shales of the grit series, and without very careful mapping it is difficult to see clearly what has taken place here, but the evidence seems to point to thrusting in a direction from north-west to south-east.

Gill Beck.—The lower part of this beck was swept quite clean to the rock floor, and at the new bridge only a few very large boulders had been left behind. Higher up the beck the débris had completely choked the channel, being piled up at a point where the course of the beck takes a sharp turn. A waterfall in Nelly Park Wood had been cut back about ten feet, and a well-defined fault clearly shown. The weirs constructed by the Bradford Corporation had been much damaged. several of the huge blocks of grit forming the aprons of the weirs having been displaced, and the residuum lodge near Gill Beck Head completely filled with sand.

Barden Beck.—This was the main channel for the water, which rose at least ten feet, as shown by the grass still clinging to the trees up to that height. Into the Upper Reservoir the water carried about 10,000 tons of material, and removed stones weighing 13 cwt. from the embankment to the bed of the stream below. Blocks of grit weighing from one to three tons had been cut from the banks and carried down stream.

Small tributary streams which ordinarily carry very little water had swollen to such proportions as to carry away large stone bridges. The residuum lodge for the Lower Reservoir was choked with hundreds of tons of material, and into the reservoir itself the stream had swept about 30,000 tons of sand, forming a huge delta.

Embsay Fell.—Here the damage done was of a very serious nature, as some mills which are situated on Embsay Beck, and use the fall of the water as their motive power, were quite wrecked. At Millholme Mill the stream is carried beneath the buildings by a culvert, which proved quite inadequate on this occasion, and the water rose at the back of the mill to such a height as to force the end wall inwards, and make its way through the mill, reaching a height of five feet, as shown by the mark on the wall (Plate LVII., Fig. 1). The mill is built upon Pendleside rocks, which dip upstream at an angle of 50°, and this no doubt proved a fortunate thing for the mill, as the water tore up the flagstones in the culvert, but could not remove the rock, as it lay, like the stones in a river bed, offering the least resistance to the onward rush of the water. At a spindle mill further up the same beck the water made its way through the back of the mill and pushed out the front wall (Plate LVII., Fig. 2). Still higher up the beck, and beyond the new Skipton Reservoir, the tributary streams Loburn Gill and Moor Beck both give evidence of the destructive work of the storm (Plate LVI., Fig. 2, and Plate LVIII., Figs. 1 and 2).

The streams draining Rilstone and Cracoe Fells show the same phenomena as I have described, though the amount of débris carried was not so great.

SIMILAR OCCURRENCES IN YORKSHIRE.

The first I can find mention of in this neighbourhood is that cited by Phillips* as occurring in 1686 in Upper Wharfedale, when gravel and sand filled the houses up to the bedroom windows.

The village of Langtoft, on the Wolds, was visited by a great storm in 1657, and a stone recording this storm, built into one of the houses, was laid bare by the adjoining house being carried away during the flood of 1892. Storms have also been recorded in this neighbourhood in 1853 and 1888.†

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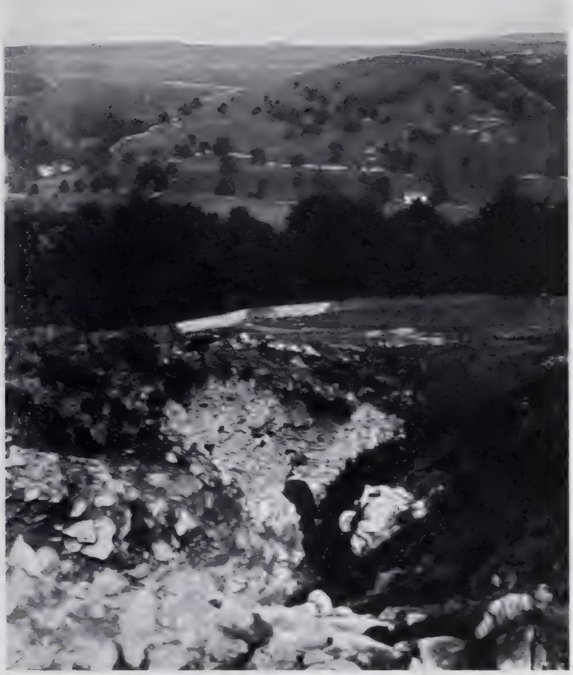
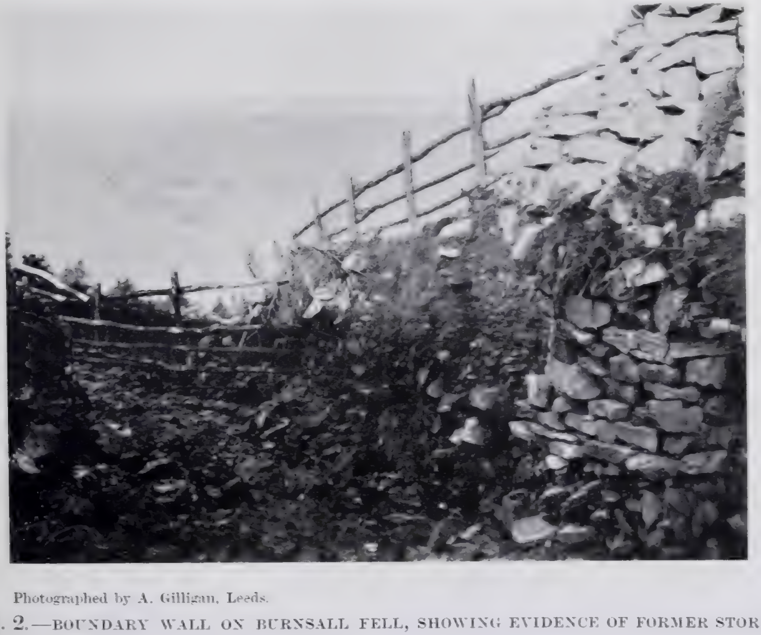
* Rivers, Mountains, and Sea Coast of Yorkshire, p. 79.

† Waterspouts on the Yorkshire Wolds, by J. Dennis Hood. Driffield, 1892.



Photographed by A. R. Dwerryhouse, Leeds.

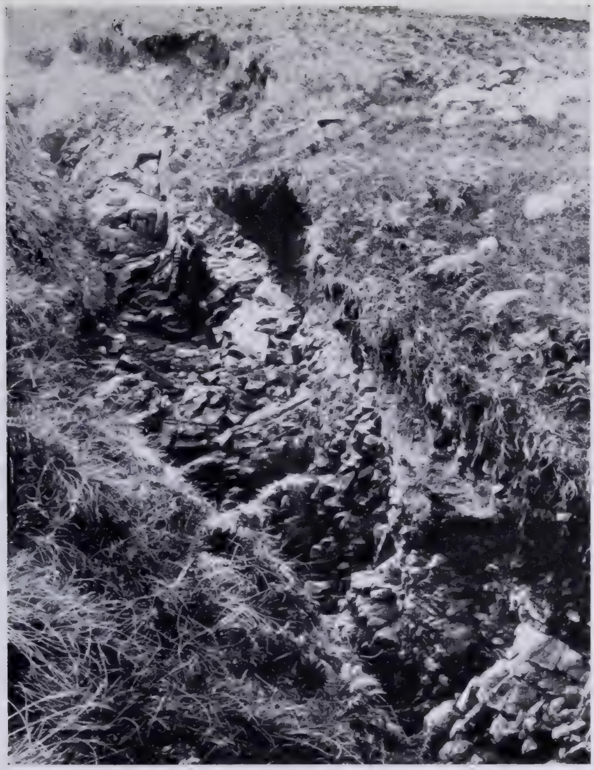
Fig. 1.—NEW CHANNEL ON BURNSALL FELL, IN MANY PARTS 15 FEET DEEP.



Photographed by A. Gilligan, Leeds.

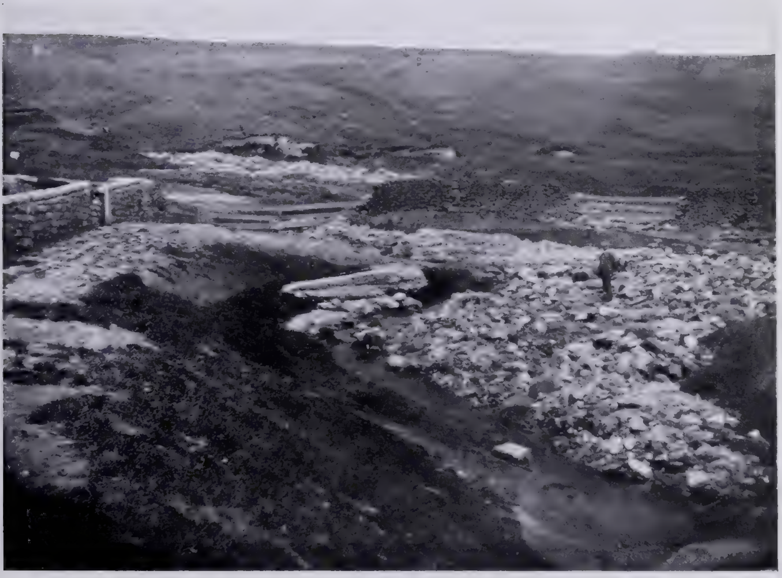
Fig. 2.—BOUNDARY WALL ON BURNSALL FELL, SHOWING EVIDENCE OF FORMER STORMS.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LV.



Photographed by A. R. Dwerryhouse, Leeds.

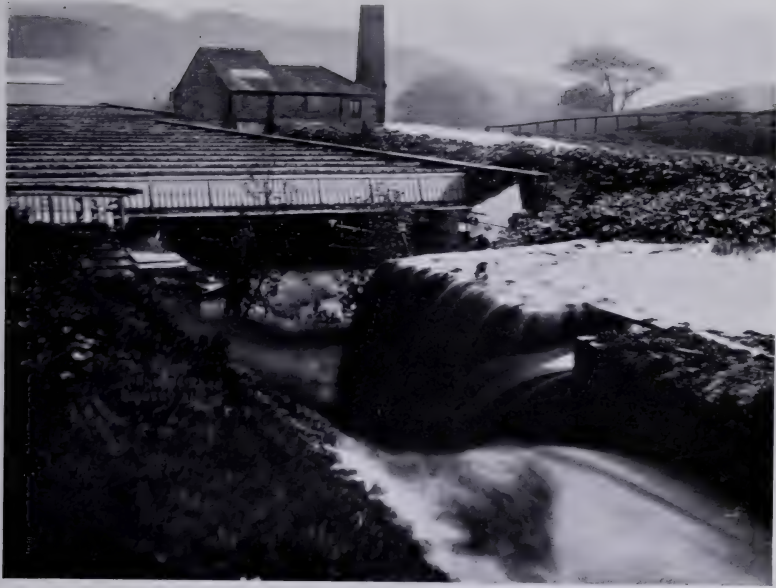
Fig. 1.—ONE OF THE NEW CHANNELS ON BURNSALL FELL.



Photographed by Miss M. Phillip, Embsay.

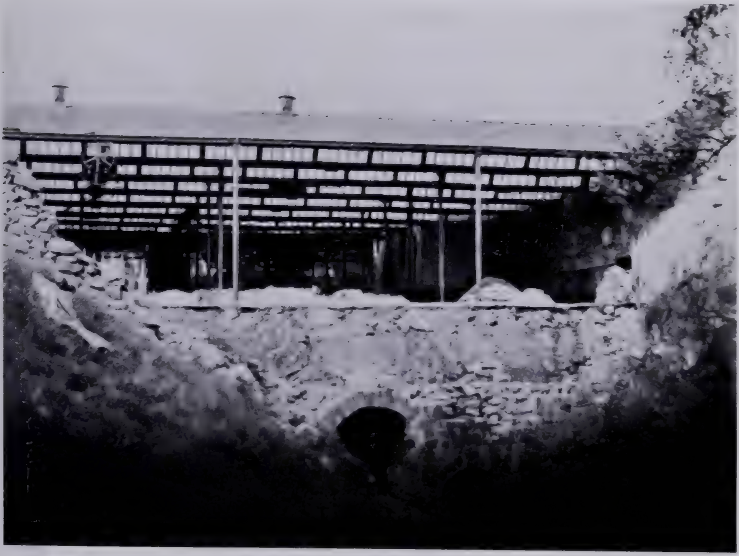
Fig. 2.—LOBURN GILL, EMBSAY FELL.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LVI.



Photographed by Miss M. Phillip, Embsay.

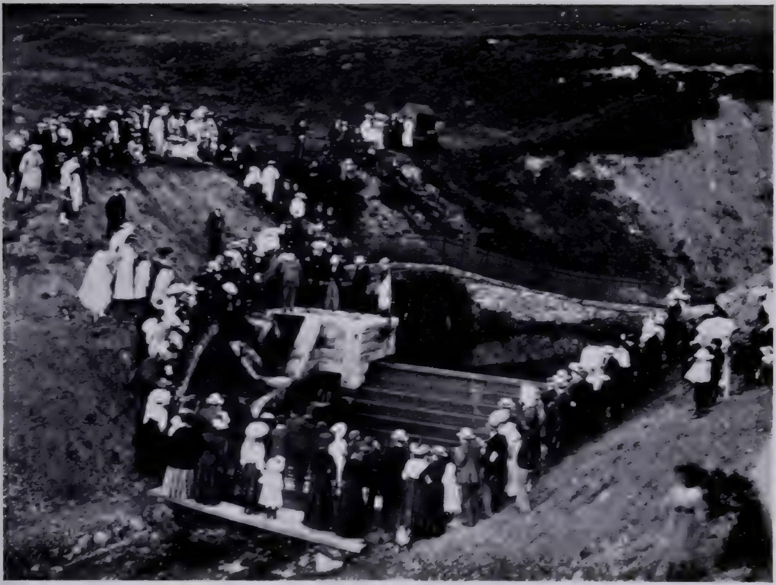
Fig. 1.—MILLHOLME MILL, SHOWING END WALL BROKEN DOWN BY THE FLOOD.



Photographed by Miss M. Phillip, Embsay.

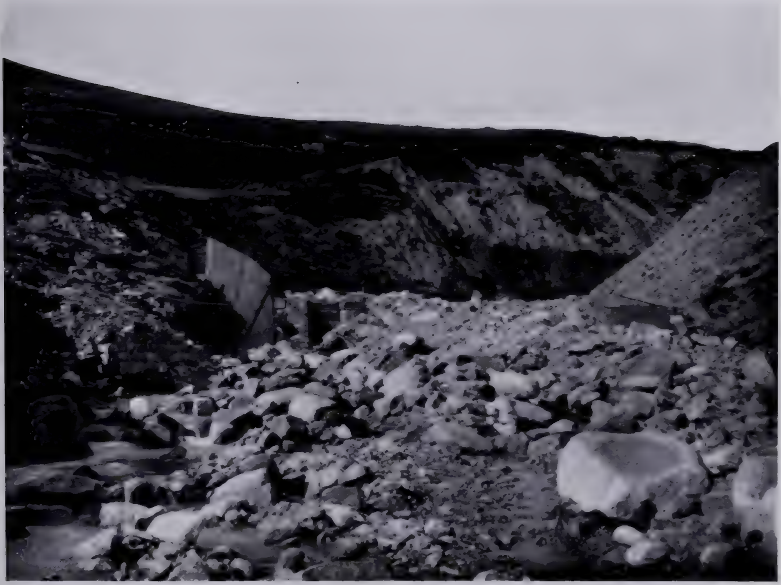
Fig. 2.—SPINDLE MILL ON EMBSAY BECK.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LVII.



Photographed by Miss M. Phillip, Embsay.

Fig. 1.—OPENING OF WEIR IN MOOR BECK.



Photographed by Miss M. Phillip, Embsay.

Fig. 2.—WEIR IN MOOR BECK AFTER FLOOD.

Proc. Yorks. Geol. Soc., Vol. XVI., Plate LVIII.

A graphic description of what is called a "Gill-brack" is given in a letter quoted in the Geological Survey Memoir on the country around Ingleborough, p. 91. This occurred in Dentdale on January 28th, 1752, and was due to the heavy rain following a fall of snow, and so causing the snow to slide bodily down the mountain side.

Ilkley was the scene of a disastrous storm on July 12th, 1900, particulars of which have been supplied me by Mr. Albert Wilson, F.R.Met.Soc., of Ilkley. The rainfall on this occasion was as much as 5·40 inches, and as the rain gauge was somewhat shaded, probably 6 inches would represent the correct amount. Much damage was done in the town, houses being thrown down and property carried away. The Wharfe rose six to seven feet, but did not overflow its banks, as it was so low prior to the storm.*

PROBABLE CAUSE OF SUCH STORMS.

Storms such as I have described are well known in all mountainous districts, from which numerous valleys radiate, and the reason assigned for them is the following :—The air which has been in contact with the earth in the valley during the sunny hours of the morning gets warmed, and, rising along the slopes, carries up the water vapour of the lower strata of the atmosphere, so that the relative humidity of the air on top of the mountain increases in the afternoon, while it decreases in the valleys below. The dynamical cooling which takes place condenses the water vapour into clouds, and when the air is damp enough they envelop the mountain tops, and not infrequently develop into thunderstorms.

Dr. Julius Hann† says : "There is a tendency to afternoon rains among mountains, and during the warmer months to thunderstorms. Such rains occur even when the general weather conditions do not indicate any precipitation, and when the general lowlands are having the most beautiful weather. These thunderstorms remain within the mountain district in which they originate, they break up towards evening, and are followed by a clear night."

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* Symon's British Rainfall, 1900, p. 16.

† Handbook of Climatology.

The weather chart for June 3rd, 1908, shows a disturbance in the Bristol Channel, and a terrible thunderstorm is recorded at Bristol, accompanied by deluging rain. This may in part account for the storm at Barden, as the disturbance travelled north-eastward.

The great amount of material which was carried down by the storm on Barden Fell makes one realise vividly the mechanical power which water possesses as a denuding agent. The quiet work of the streams and rivers of the world is great, but no doubt storms aid them in their destructive work more than we are accustomed to imagine, bringing down the material from the higher land in such a form that the river can easily transport it.

The torrential rains of the tropics must do enormous work; for instance, those which occur at Cherrapongee, in the Khasia Hills of Assam, where 40 inches have been known to fall in one day and 800 inches in the year, the bulk of the rainfall occurring during the prevalence of the south-west monsoons, from June to December.

My thanks are due to Miss M. Phillip, Embsay, and to Dr. Dwerryhouse for permission to use the photographs illustrating this paper, and also to Mr. G. V. Wilson for his help in the field.

NOTES ON A JUNCTION OF COAL MEASURES AND MILLSTONE GRIT AT HAWKESWORTH QUARRY, HORSFORTH.

BY ARTHUR R. DWERRYHOUSE, D.SC., F.G.S.

(*Read 20th February,* 1908. *Manuscript received 20th February,* 1908.)

Over a considerable tract of country, from the neighbourhood of Thorner to Horsforth, the Yorkshire Coalfield is cut off to the north by a fault, or series of faults, which brings in the Millstone Grit.

To the north of this line of fault there are several outliers of Coal Measures which exhibit the normal junction with the Millstone Grit.

These are at Chapel Allerton, Hawkesworth Quarry, Rawdon, and Baildon, and it is in one of these, viz., at Hawkesworth Quarry, that the exposure described in the present note occurs.

The section in the quarry is continued to the neighbouring railway cutting and shows the Coal Measure shales dipping to the southward and resting upon the " Rough Rock," the uppermost member of the Millstone Grit series.

Both the shales and grits are quarried, the former for brickmaking and the latter being an excellent building stone.

In the course of the removal of the overlying shales, the surface of the Millstone Grit has been exposed over a considerable area, and during a recent visit of the members of the Leeds Geological Association I noticed that this surface presented a very curious appearance, consisting of a number of hummocks, flat on the top, with steep sides, and separated from one another by hollows, which on investigation I found to be old water channels.

The whole surface resembled in a striking manner the sandbanks which form the submerged delta of the Mersey, and which are exposed at low water of spring tides.

The deposition of mud followed the formation of the channels immediately, as otherwise the outlines of some of the smaller runnels must have been obliterated.

Accordingly we find some of the channels filled in with shales containing thin bands of Carbonaceous material (Fig. 1).

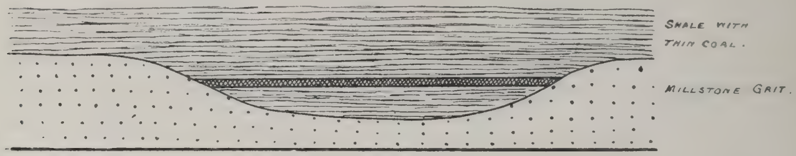

Fig. 1.

It would thus appear that the change of conditions came on very rapidly at this point, and it may be that here we have the fossil impress of the last tide, or perhaps the last flood that passed over this part of the Millstone Grit delta.

The general relation of the rocks will be seen from Fig. 2.

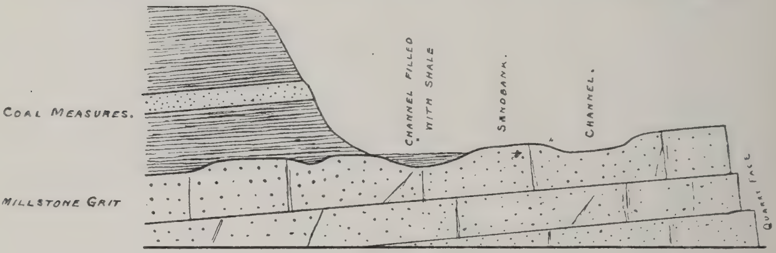

Fig. 2.

A bed of coarse grit, closely resembling the Millstone Grit below, occurs about 15 feet up in the Coal Measures. It is about five feet in thickness and indicates that there were occasional recurrences of the conditions under which the grits were formed.

The presence of thin coals in the shales of the Millstone Grit series, and of coarse sandstones in the Coal Measures, shows that there was really no sudden change in the conditions, but merely a gradual passage from outer estuarine to landward swamp.

My thanks are due to Messrs. B. Whittaker & Sons for the facilities which they have kindly given me in the examination of this interesting section, and I hope to be allowed to follow up the workings in order to ascertain if any further light be thrown upon the matter as the excavation proceeds.

SOME UNDESCRIBED FAULTS IN THE SETTLE-MALHAM AREA.

BY COSMO JOHNS, M.I.MECH.E., F.G.S.

(*Read* 12*th November*, 1908. *Manuscript received* 20*th December*, 1908.)

INTRODUCTION.

The district about to be described may be considered as having the railway from Settle to Carlisle as its western boundary, the inner Craven fault, which runs from Great Stainforth by Black Hill and past the upper portion of Goredale, defines it to the north, while the more irregular line mapped, on Sheet 92 N.W. of the Geological Survey 1 in. map, as the outer Craven fault, might be taken as the southern limit (see Map, Fig. 1). It is a country of bare limestone scars, dry valleys, and deep-cut gorges. The scars have been carved into fantastic shapes, while screes cover the lower slopes. Immediately above Victoria Cave is the long line of scars known as Langcliffe Scar, and from the top, looking E. and N. can be seen the huge dip slope of the Great Scar Limestone, relieved only by the rounded eminence of Black Hill, with its Grit capping and attenuated representative of the Yoredale series. The continuity of this series of shales, and one, if not two, limestones with the Yoredale rocks of Fountains Fell immediately N. is perfectly clear. Their preservation is due to a complex series of faults trending N.W. and S.E., which have let them down in the Great Scar Limestone.

The upper beds of the Great Scar have been denuded from the greater portion of the dip slope mentioned, but within the area covered by the Yoredale shales several stream sections can be seen, and the coral fauna, with *Amplexi-Zaphrentis* as the most typical form, enables the correlation of these beds with the black bituminous limestones of the top of the Great Scar Limestone of Ingleborough, Penyghent, and the S.W. side of Langstrothdale, to be made with some certainty. The same coral fauna has been determined from the top beds of the limestone massive, near New Houses, 1½ miles E. of Goredale,

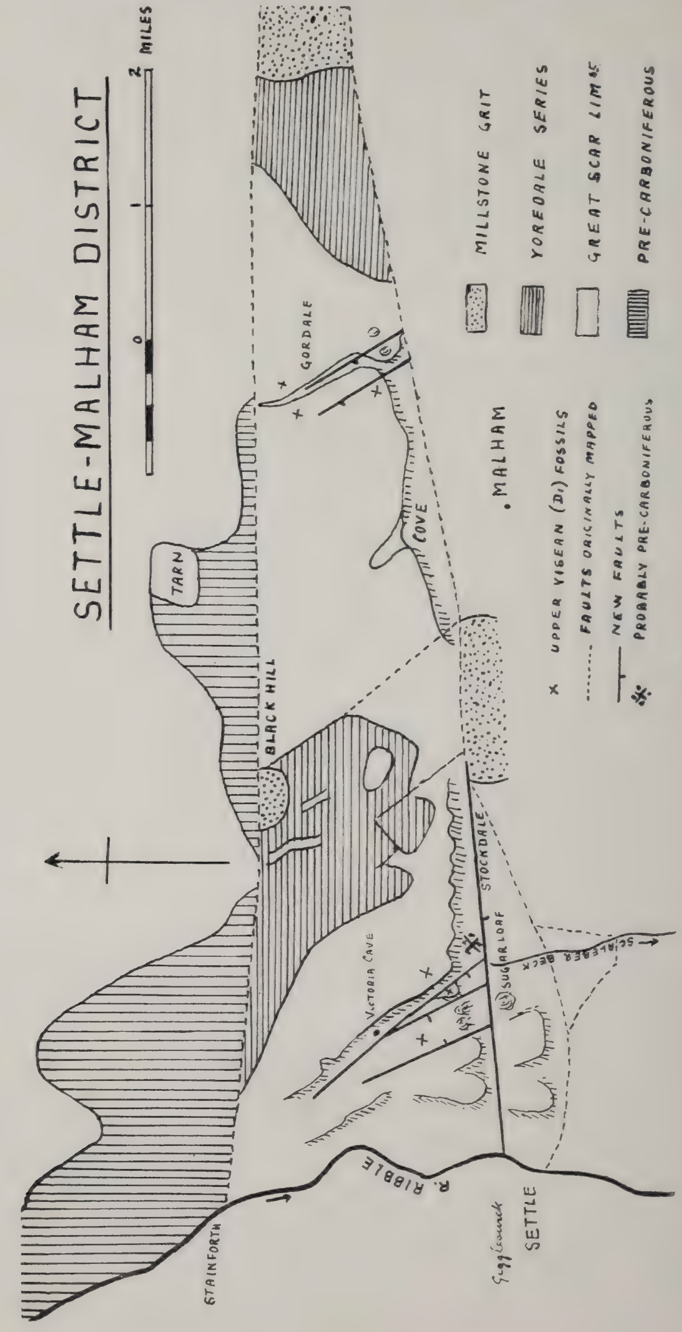
SETTLE-MALHAM DISTRICT
0
1
2 MILES
GORDALE
MALHAM
COVE
TARN
BLACK HILL
STOCKDALE
SUGAR LOAF
Victoria Cave
SCALEBER BECK
R. RIBBLE
STAINFORTH
Giggleswick
SETTLE
MILLSTONE GRIT
YOREDALE SERIES
GREAT SCAR LIMS.
PRE-CARBONIFEROUS
× UPPER VISEAN (D_1) FOSSILS
FAULTS ORIGINALLY MAPPED
NEW FAULTS
PROBABLY PRE-CARBONIFEROUS

Fig. 1.

where Yoredale shales succeed as near Black Hill. It is clear therefore that we are dealing with a faulted mass of Great Scar Limestone; that the very top beds of this limestone, where preserved, represent the top of the Great Scar in the unfaulted area to the north, and are succeeded by Yoredale beds near Black Hill.

Structural Features.

As originally mapped it would appear that the area is a mass of Great Scar Limestone, out of which the many hills, valleys, and gorges have been carved. At the time the survey was made the determination of faunal horizons in the lower Carboniferous rocks had not been accomplished. The lithological variations in the limestone itself were not sufficiently apparent to enable displacements in the limestone to be mapped except in a few instances. It would appear therefore that the outer fault as traced represents the faulted junction of the grits or underlying shales with the limestone. This reading gave rise to many difficulties, and has been recognised by everyone who studied the area in detail. It involves the assumption that between the two Craven faults we have a mass of Great Scar Limestone, much exceeding in thickness that to be observed north of the inner fault. As, however, the base of the limestone cannot be seen the observed discrepancy in thickness would be a minimum.

The older writers have referred to an exposure of Silurian rocks near the entrance to Gordale. It is not visible now, though the occurrence of strong springs at the foot of the scar on the right-hand side looking up the gorge renders it very probable that pre-carboniferous rocks are not far below the lowest limestone exposed at Gordale and Malham Cove. If this could be demonstrated, then it is very probable from such palæontological evidence as is available that the basal beds, both here and below Fountains Fell, are of the same age. At this point therefore the evidence goes to show that the discrepancy in thickness cannot be a great one. It is near Settle that the great difficulty arises, for if the plane of the dip slope above Langcliffe Scars be produced either to the west or south, and a perpendicular dropped from that plane to the lowest exposed limestone at the boundaries of our area, we get an apparent thickness which might be estimated at 1,200 feet. If the faunal horizon adopted as base of the Dibunophyllum zone be taken as the datum plane, a still greater thickness must be assumed, for the faunal line dips more steeply to the N. or N.E. than the top of the limestone. As the observed thickness of Great Scar Limestone north of the inner fault is about 500 feet, the discrepancy is a very serious one.

PREVIOUS OPINIONS.

It is somewhat difficult to discover what the older writers considered to be the actual line taken by the outer fault, in the absence of a detailed map, other than that it continued from Giggleswick Scar past Ryeloaf Hill to Malham. Davies,[*] in his description, mentions that

> "The limestone scar behind Settle is a continuation of the fault, and, still proceeding eastward, the grand series of scars of Attermire and Langcliffe, perhaps the finest along the whole line of dislocations, extend towards Malham. They form dry hills to the left of the road, whilst to the right are wet surfaces of Millstone Grit, the road being near the line of fault."

This would approximate to the line drawn by Mr. Tiddeman, the junction of grit and limestone being the chief point noticed. The only writer who seems to have suggested a radical change in the line mapped as the outer fault is Dr. Marr,[†] who came to the conclusion that this fault (the "middle" of his paper) represented a thrust plane, but as the line, as mapped, indicated the apex of the V pointing south gave reasons for drawing the fault line further north.

> "Examination of the area shows that the continuous scar which, I believe, marks the boundary of the fault, runs far north of this along the Settle and Beacon Scars (Attermire Scars), and so to the Ribble between Settle and

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[*] West Yorkshire, Davies & Lee, p. 7.

[†] Q.J.G.S., Vol. lv., 1899, p. 352.

> Langcliffe, and on the west of the valley runs at the back of the hill above Giggleswick, thus cropping out with a V-shaped outcrop, of which the apex points up the valley."

Dr. Marr goes on to describe the occurrence of Knoll limestones, with a fauna similar to that of the Cracoe Knolls, south of the line he suggested for the fault and above Scaleber Force. Even this, however, does not explain the great discrepancy in thickness if measurements be made west of scar above Victoria Cave. Many observers seem to have suspected transverse faults, Upper Winskill in the west and Goredale to the east of our area being instances, but it does not appear that any records of their observations have been published, or that any explanation of the observed difference in thickness of the Great Scar Limestone between and north of the faults has been offered.

THE FAUNAL SEQUENCE.

The previous workers, with the exception of Dr. Marr, who recognised the existence of Knoll limestones with their characteristic fauna, depended on lithological differences in determining the lines of dislocation. As this present account is based on palæontological evidence in addition, it becomes necessary to give a brief description of the faunal sequence. The Great Scar Limestone can most conveniently be divided into two divisions, an upper and a lower. As exposed north of the faults it corresponds to the Viséan of the S.W. Province and of Belgium. The lower division is distinguished by the absence of *Giganteid producti* and corals of the genus *Dibunophyllum.* The horizon where these enter, together with the associated fauna of which *Cyrtina septosa* is the most striking brachiopod, constitutes the base of the upper division. The lower division corresponds to the Seminula zone of Dr. Vaughan, while the upper corresponds to the Dibunophyllum zone.

It is this base of the upper zone, with its first maximum of *Productus* "*giganteus*" and the *Dibunophyllid* corals, which has been used in this investigation as a faunal horizon, in the same way that one would have used a well-marked and persistent shale bed if such existed in the Great Scar Limestone. The value of such a faunal line depends on its persistence over a wide area, the constancy of its relation to other well-marked faunal horizons and any lithological changes, and its determination in the field. The line adopted fulfils each of these conditions. It has been mapped over a wide area in N.W. Yorks.; it always occupies the same relative position in the faunal sequence. It is associated with strong grey limestones that weather into well-marked scars, and succeed softer, purer limestone. The faunal characteristics can, when once determined, be easily recognised in the field. Coming in abruptly as it does, after a series of relatively unfossiliferous beds, the new fauna, with its *Giganteid producti* and easily distinguished *Dibunophyllid* corals, can always be picked up if clear sections are available.

THE GORDALE FAULTS.

In the ascent of Gordale the most striking feature is the manner in which the great thickness of apparently unfossiliferous limestone is succeeded at the very top by a thin band crowded with large *Producti* and corals. This fossiliferous bed can be found on both sides if one works back a little. Sometimes it remains as isolated patches, forming outliers of Upper Viséan beds, where denudation has removed the rest. *Giganteid producti, Dibunophyllids, Carcinophyllids, Cyathophyllum Murchisoni*, and an occasional *Cyrtina septosa* make it clear that we have here the main entrance of the Upper Viséan fauna. When the level of patches of these beds on opposite sides of Gordale is compared, there appears to be a displacement with the downthrow on the western side. The difference in level is not much, perhaps 10 feet is the extent. At the lower end of the gorge, where one has in ascending to leave the stream bed and climb up the talus on the left side, the actual fault can be seen, and the displacement measured. The downthrow here is again to the west, and the actual displacement is about 21 feet. Starting at the top, or northern end of the gorge, the stream flows south for about a quarter of a mile, then bends round to the S.S.E., in which direction it runs for half a mile. It is then that a sharp turn in a S.W. direction is taken for the stream to flow over the accumulation of calcareous tufa which blocks the entrance to the gorge. It is this intermediate half mile of the gorge which follows the fault line. The continuation of the fault itself to the S.S.E. can be traced over the top of the scars between L and E of Dale on the one-inch map. The Gordale fault therefore trends N.N.W. and S.S.E., with a small downthrow to the west. There is no hade, and the displacement has taken place along one of the master joints. About 150 yards west of and parallel to the fault just described is another. The throw here is greater, and again is on the western side. A distinct break in the lines of scars can be seen west of the actual entrance to Gordale, and at the top fossiliferous Upper Viséan limestone is on the same level as older limestones. The evidence here is not so clear as in the previous case, and the actual amount of displacement cannot be determined.

THE VICTORIA CAVE FAULTS.

The striking line of precipices known as Langcliffe Scars, about the centre and half way up the slope of which is the famous Victoria Cave, is a well-known feature. Roughly they run N.N.W., and the line, if produced in a southerly direction, intersects the long E. and W. line of scars known as the Beacon and Attermire Scars, near the rifle butts. Beneath Langcliffe Scar is a long valley which at its southern end makes the striking break between Beacon and Attermire Scars. In the middle of this valley is small exposure of limestone of *Dibunophyllum* or D_1 age. The whole of Langcliffe Scar, as seen from that point, is of Seminula age, and it is necessary to climb to the very top before D_1 beds are found. A fault therefore runs along the foot of these scars, and the throw at this point cannot be less than 300 feet, and is perhaps nearer 400. Another fault with a considerable throw runs on the western side of the exposure of D_1 limestone, and thus defines the position of the valley, at least at the southern end. Owing to the dip of the beds above Langcliffe village the throw of this second fault diminishes as it is traced north, and there are indications that it might even be reversed as it approaches the road leading down to the village. Near the rifle butts the two faults form the trough, with Beacon and Attermire Scars on either side. Seen from High Hill, or Sugarloaf Hill, the dislocations can be clearly distinguished when their significance has been pointed out. Measured from Victoria Cave to Langcliffe village the effect of the faults is to considerably reduce the apparent thickness of limestone.

There can be no doubt that there are many more of these transverse faults. One with a considerable downthrow on the western side must run between Upper Winskill and Langcliffe Scar, for the D_1 beds at the top of the quarry of the Craven Lime Works are much below any of those described, but the tracing of the actual fault lines is difficult, and would require a more minute faunal investigation than it has been possible to undertake. Mention, however, might be made of the small fault, if 150 feet throw can be called small, which forms the ledge near Attermire Cave. This is the most striking instance of the repetition of the same faunal line by normal faulting. The cutting off by the important E. and W. fault about to be described of the southern extremity of this fault and its significance will be referred to later, when discussing the probable occurrence of pre-carboniferous rocks at that point.

The Stockdale Fault.

Structurally this is the most important fault of those to be described. If a line be drawn from "Giggleswick" to "Stockdale" Farm it follows, in a great part, a much used path on the left of which, going east, we have a long line of continuous scars, interrupted only by the trough near the rifle butts already described as marking the position of the two N.N.W. faults below Langcliffe Scar. The dip slope of High Hill is a marked feature on the right-hand side when the ground opens out and the curious eminence of Sugarloaf Hill appears. From there on we are in the Stockdale valley, with low-lying ground to the right and precipitous scars to the left. The topography alone suggests dislocations, and an examination of the sections to the south confirms this. Scaleber Beck reveals a number of sections, of which inconsistent dips are the chief characteristics. Many of the exposures are fossiliferous, and are clearly high up in the Great Scar Limestone. A little further north, but in the same line as the break in the E. and W. scars, is Sugarloaf Hill. Here we have the irregular bedded pale limestones, with the usual "Knoll" brachiopods, which, though different from the well-bedded limestones in and near the beck, are still of Upper Viséan age. It is significant that if the two faults marking the break in the scars above the rifle butts be prolonged to the south, they would include between them these exposures of Upper Viséan limestones and Sugarloaf Hill itself. High Hill is of Lower Viséan age, and calls for a fault between it and Sugarloaf. The steep, northerly dip of High Hill, as compared with the scars facing it, demonstrate the existence of a fault between them, and there can be no doubt that the real outer Craven fault runs at the foot of the long E. and W. line of scars, and follows approximately the path mentioned above. The area between this line and that drawn on the one-inch map of the Survey is occupied by a much-faulted complex of Great Scar Limestones.

It is significant that at the point where the Attermire Cave fault is cut off by the Stockdale fault we have, going east, the commencement of a line of strong springs at the foot of the scars. It is difficult to explain their presence except by assuming that they indicate the position of an impervious barrier of pre-carboniferous rocks. If this be so, then such faunal evidence as is available would point to the lowest limestone being on the same horizon as the basement beds north of the inner fault viz., low S_2.

CONCLUSIONS.

The results of this investigation might be briefly stated thus:—

> The apparently great discrepancy in thickness between the Great Scar Limestone exposed between and north of the Craven Faults has been much diminished.
>
> A N.N.W. series of normal faults have caused a repetition of the same beds.
>
> The Craven Faults are shown to be best expressed within this area by two nearly parallel step faults running E. and W., viz., the inner, or Great Stainforth, fault, and the outer, or Stockdale, fault.

The much faulted ground between the Stockdale fault and the Millstone Grit boundary to the south is closely related structurally to the area beyond, and can best be discussed in connection with it.

The suggestion of Dr. Marr that the outer Craven fault (middle of his paper) runs along the Beacon and Attermire Scars is now confirmed.

The age of the E. and W. and the N.W. or N.N.W. fault systems and their relation to the important E. and W. anticlines, can only be profitably discussed when the facts relating to the eastward and westward extension of the faults can be reviewed. For the same reason, no attempt has been made in this paper to discuss the differences of opinion that exist as to the correlation of the rocks north and south of the Craven Faults.

In concluding, an acknowledgment should be made of the generous assistance which the writer has received. The work done in this particular area was based on, and only possible through, the results of an investigation of the Carboniferous rocks north of the faults. During that investigation much assistance has been received from many officers and members of the Yorkshire Geological Society and the Geological Section of the Yorkshire Naturalists' Union, among whom special mention should be made of Mr. H. Culpin, of Doncaster, and Mr. W. Robinson, of Sedbergh. Dr. Wheelton Hind has not only placed his detailed knowledge of N.W. Yorkshire at the writer's disposal, but has visited the district many times during the progress of the work, besides determining many of the fossils. Dr. Arthur Vaughan not only undertook the onerous work of determining all the corals and most of the brachiopods, but has been unwearying in discussing the many difficulties that have arisen from time to time. For the conclusions recorded in this paper the writer is solely responsible.

NOTES ON THE DEVELOPMENT OF THE YORKSHIRE COALFIELD IN THE NEIGHBOURHOOD OF DONCASTER.

BY WALTER ROWLEY, F.S.A., M.INST.C.E., F.G.S.

(*Read* 12*th November*, 1908. *Manuscript received* 26*th December*, 1908.)

To-day recalls to my mind a meeting of this Society, which has for half a century done more than any other institution for promoting the geology of mining in its early days, at Doncaster on the 28th September, 1870, when as a very young man, just out of his teens, I ventured, with the confidence of youth, to read a paper on "Some Observations on Coal and Coal Mining."* Perhaps it might be of interest to read you an extract from that paper where it refers to Doncaster at that date, as follows :—

"To our local friends in the neighbourhood of Doncaster the economical working of our coalfield is a matter of great interest, standing, as at present we do, upon those coal measures underlying the Permian Rocks, a section of which I have added to my illustrations, calculated from what I consider the most reliable data ; their value and extent may be estimated by one fact, viz., that in this section are represented all the seams belonging to the Yorkshire Coalfield, numbering nearly 40, with an aggregate thickness of nearly 90 feet, at least 30 feet of which will be workable sooner or later in this district. . . . . . The above rocks will have to contribute the coalfields of future generations ; at the same time, situated as the upper portions of this coalfield are, within a practicable depth, I do not see any reason why it should not contribute its share to the requirements of the present century, and I express my astonishment that it has not already been developed, and thus locally derive the advantage of the excellent colliery sites which are to be found in the vicinity of Doncaster. . . . . With a willing and liberal proprietary, I think it possible that enterprising capitalists can be found to develop such vast resources."

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* Some Observations on Coal and Coal Mining, and the Economical Working of Our Coalfields. By Walter Rowley, Mining Engineer, Leeds. Proc. Geological and Polytechnic Society of the W. Riding of Yorkshire, Vol. V., pp. 229-246.

In my opinion Doncaster is unequalled in its geographical position by any colliery district in the kingdom.

I think it well to mention that, according to the section mentioned in that paper, I estimated the depth of the Barnsley Bed at a maximum of 700 yards, with a total thickness of 10 feet 2 inches. Therefore you will see that I have not been very much out in the depth and thickness in my estimate of that date. Undoubtedly, although the Doncaster neighbourhood has taken some considerable time to develop, it will be in the future one of the greatest mining districts in Great Britain. I do not particularly refer to the number of collieries, but to the size of the shafts that are being put down and the output that will be obtained.

Bentley will soon be in a position to draw a large tonnage of coal per day, and we have also Brodsworth in the district.

At Cantley a bore hole is being put down, which will doubtless mean in the course of another 3 or 4 years coal being drawn from this part, while south of Doncaster we have another site taken up by Staveley Company, where I understand that operations will soon be commenced; and north of Bentley, at Carcroft, there is a sinking in progress known as Markham's, and the mining district of Maltby is rapidly extending to the historic castle and royal manor of Tickhill, owned by the Duchy of Lancaster.

You will therefore see that Doncaster will, before long, realise fully what I prophesied of it in 1870, and is becoming the centre of a coalfield upon which future generations will have to a certain extent to depend for their supplies, it being the largest, not fully developed, coalfield in Great Britain.

HONORARY SECRETARIES' REPORT, 1908.

The work of the Society has been carried on smoothly and successfully for another twelve months. The number of members reported at the close of last year was 218. During the year we have lost by death three valued members of our Society, Dr. H. Clifton Sorby, F.R.S., one of the foremost scientific men of this generation, whose love for and interest in Yorkshire geology never flagged, and was for 57 years a member of our Society; Sir Thomas Brooke, Bart., of Huddersfield, who had been a member for 31 years, and Mr. John Farrah, F.R.Met.S., of Harrogate, who joined the Society in 1895. Five members have resigned their membership, but nine new members have been elected, leaving a net gain of one at the close of the year.

At the Centenary celebration of the Geological Society this Society was represented by a delegate, Rev. C. T. Pratt, M.A. At the February Council Meeting a letter was read from the President and Secretaries of the Geological Society thanking us for our address of congratulation and representation by a delegate, and asking our acceptance of a copy of the "History of the Geological Society" for our library, as a memento of this interesting celebration. The letter was ordered to be entered on the minutes and thanks were returned for the gift of the History. At the same Council Meeting Dr. A. R. Dwerryhouse, the Hon. Librarian, was able to report that the library had been satisfactorily housed in the Geological Department of the Leeds University, and he was authorised to try to arrange to obtain the missing parts of journals which were not complete. The Trustees of the library, Messrs. W. Simpson and F. W. Branson, reported the completion of the deed transferring the library to the custody of the Leeds University, and its deposit with our Bankers. Two members of your Council were appointed officers of Section C (Geology) of the British Association for the Dublin Meeting, J. Lomas (Recorder) and W. Lower Carter. Mr. J. G. Robinson, J.P., attended the meeting of the Corresponding Societies' Committee, at Dublin, as our delegate.

The Spring General Meeting was held in the Geological Department of the Leeds University on February 20th, under the presidency of Mr. C. W. Fennell, when papers were read by Mr. H. Culpin on " Marine and other Fossils in the Yorkshire Coal Measures above the Barnsley Seam "; by Dr. A. R. Dwerryhouse on " A Junction of the Millstone Grit and Lower Coal Measures at Horsforth " ; and by Mr. Albert Wilmore on " The Dark Limestones of the Craven Lowlands." The same morning a Field Excursion was taken to see the interesting section at Horsforth described in Dr. Dwerryhouse's paper.

A very cordial invitation was received from the Liverpool Geological Society to unite with them in a Field Excursion to the Berwyns at Easter. This was accepted, and a large and vigorous party met at Oswestry and enjoyed several days' interesting field work under the leadership of Mr. J. Lomas, F.G.S. An address was delivered by Dr. Wheelton Hind on " The Carboniferous Limestone of North Wales," and Mr. Lomas gave a lucid account of the geology of the district visited. At that meeting the following resolution was adopted :—

" That this Society sincerely regrets the great loss to geology and the allied sciences caused by the death of Dr. H. Clifton Sorby, F.R.S., and desires to place on record its sense of the incalculable services which have been rendered to the advance of scientific knowledge by his indefatigable researches, pursued with unremitting vigour until within a few days of his death. The Society also deplores the loss of one who has been for 57 years one of its members, and whose genial and inspiring friendship has been a stimulus and an inspiration to his fellow-members, and recalls with satisfaction that many of his earlier geological papers were read at its meetings and published in its Proceedings."

The Summer General Meeting and Field Excursion was held at Richmond, June 19th to 22nd, under the chairmanship of Mr. J. J. Burton, and with the valued co-operation of Mr. Wm. Horne, F.G.S., as leader. Careful attention was directed to the Carboniferous rocks below the Millstone Grit, and the evidence for glacial action and river diversion was noted. At the meeting a discussion was held on " The Upper Limit of the Lower Carboniferous Rocks."

The Autumn General Meeting and Field Excursion was held from September 24th to 28th, in North-east Yorkshire, with Saltburn as centre, under the leadership of Professor P. F. Kendall and Mr. J. W. Stather. At the General Meeting, under the chairmanship of Mr. J. W. Stather, F.G.S., in place of Dr. W. Y. Veitch, who unfortunately was prevented from attending by indisposition, a paper was read by Mr. Frank Elgee, of Middlesbrough, on "The Glaciation of North Cleveland."

At the close of the year the Hon. Librarian was able to report that further consignments of books belonging to our library had been received from Mr. Crowther, the Curator of the Philosophical Hall, and it was hoped that before long many more of the gaps in the series of Transactions would be filled up. It had not been thought desirable to commence the Catalogue at present, but it was hoped that it would be able to be undertaken in the near future.

The Council recommend the following as the localities for the General Meetings and Field Excursions for 1909 :—

1.—The usual Spring Meeting in Leeds.
2.—A long Excursion at Easter to Kirby Lonsdale.
3.—A short Excursion in June to Cloughton Wyke.
4.—An Excursion to Gainsborough and Scunthorpe in September to examine the Rhaetics and Lias.

The Proceedings, Vol. XVI., Part II., was issued at the end of 1907, and it is hoped that Part III. will be in the hands of the members before the end of the year.

Our Proceedings have been sent out as usual to Scientific Societies, and the following Societies have sent us their publications in exchange, for which we tender our best thanks :—

Abbeyville, Société d'Emulation d'.
American Institute of Mining Engineers.
American Philosophical Society.
Antonio Alzate, Soc. Cientifico.
Australian Institute of Mining Engineers.
Australian Museum.
Birmingham and Midland Institute.
Boston Society of Natural History.
Bradford Antiquary.
British Association for the Advancement of Science.
British Museum.

Brooklyn Institute.
California, University of.
Cambridge Philosophical Society.
Chicago Academy of Sciences.
Copenhagen, L'Academie Royale des Sciences et des Lettres.
Elisha Mitchell Scientific Society.
Geological Society of London.
Geologists' Association.
Harvard Museum of Comparative Zoology.
Hertfordshire Natural History Society.
Iowa Geological Survey.
Leeds, University of.
Manchester Geographical Society.
Manchester Geological and Mining Society.
Manchester Literary and Philosophical Society.
Maryland Geological Survey.
Mexico, Inst. Geologico de.
Michigan Academy of Science.
Moscow, Société Impériale des Naturalistes de.
New Brunswick, Natural History Society of.
New South Wales, Department of Mines.
New South Wales Geological Survey.
New York Academy of Science.
New York State Museum.
North of England Institute of Mining Engineers.
Nottingham Naturalists' Society.
Peru, Cuerpo de Ing. de Minas.
Philadelphia Academy of Natural Science.
Royal Dublin Society.
Royal Geographical Society.
Royal Geological Society of Cornwall.
Royal Physical Society.
Royal Society of Edinburgh.
Royal Society of New South Wales.
Russiche K. Mineralog. Gesellschaft.
Smithsonian Institution.
Southport Society of Natural History.
St. Pétersbourg, Comité Géologique.
St. Louis Academy of Science.
Tokyo College of Science.
United States National Museum.
United States Geological Survey.
Upsala, University of.
Vienna, Naturhistorischen Hofmuseum.
Wisconsin Academy.
Yorkshire Philosophical Society.

EXCURSIONS, 1908.

In connection with the Spring Meeting, held at Leeds on February 20th, 1908, an excursion was arranged to Hawkesworth Quarry, Horsforth, under the leadership of Dr. A. R. Dwerryhouse.

The members met at the Headingley tramway terminus and walked to the quarry, where the junction of the Coal Measures and Millstone Grit was examined.

The section is described on pp. 391 and 392.

The return journey was by way of the woods and the Horsforth tramway route to Leeds.

The thanks of the members present were accorded to Messrs. B. Whitaker & Co. for their kind permission to visit the quarries.

EASTER MEETING.

In 1907 the members of the Liverpool Geological Society joined us at Colne, and this year the Council of the Yorkshire Geological Society accepted the invitation of the Liverpool Society to join them in a field meeting in the district round Oswestry. The members of both Societies took up their quarters at the Wynnstay Hotel, Oswestry.

The meeting was well attended, there being between 30 and 40 members of the two Societies present during some part of the time.

Dr. Dwerryhouse, who is this year President of the Liverpool Geological Society, was present and occupied the chair at the evening meetings, while the field excursions were under the able leadership of Mr. Joseph Lomas, F.G.S., who has been working in the district for some years. On the evening of Thursday, April 16th, the members assembled at the Wynnstay Hotel, and a start was made on the morning of Friday, April 17th, at 9 a.m.

The party first drove to Selattyn in the neighbourhood of which several exposures in the Carboniferous Limestone Series were examined.

The first exposure was in a quarry on the hillside to the north of Selattyn, where a cherty limestone was exposed. Here a search was made for fossils, with a view to determining, if possible, the exact horizon of the beds, but owing to the extensive decalcification which had taken place, such remains as were found could not be identified with certainty.

In the upper part of this quarry several beds of chert with quartz pebbles occur, the joints in the rock passing indiscriminately through both the matrix and the pebbles. The dip of the beds was found to be about 20° to the south.

The limestone quarries at Craig Nant were next examined, and although fossils were not numerous, a sufficient number was found to justify the placing of the beds in the upper part of the zone D_2.

The limestones were found to be much more massive than those in the quarry described above, blue in colour, and to have suffered much less alteration.

They lie immediately below the cherty beds mentioned above.

In a second quarry, also at Craig Nant, a bed of shale was seen to underlie the massive limestone, but was separated from it by a series of thin bedded limestones.

The following fossils were obtained from the Craig Nant sections :—

Diphyphyllum.
Lithostrotion irregulare.
Lonsdalia floriformis.
Cyclophyllum.
Dibunophyllum.
Syringopora sp.
Productus sp.

Many of the bedding planes showed deposits of tufa similar to that which occurs in the knoll-reefs in the neighbourhood of Clitheroe in Lancashire, and in those of Yorkshire and the Isle of Man.

The presence of *Lonsdalia floriformis* marks these beds as belonging to the zone of D_2.

The limestones are covered by a layer of glacial drift of varying thickness, containing many boulders of local rocks, together with some northern erratics, which include the granite of Eskdale (Cumberland) and Andesitic rocks from the Borrowdale Series of the Lake District.

Close to the Craig Nant Quarries the ancient earthwork of Offa's Dyke was crossed, and could be seen extending across the country in both directions for some distance.

From Craig Nant the party drove towards Llansantffraid Glyn-Ceiriog, alighting about half a mile above the village to examine a quarry in the Hirnant Limestone of the Upper Ordovician, where a few specimens of *Orthis* were found in the more calcareous portions.

The road from Craig Nant to Glyn runs in its upper part through a valley which cuts through the watershed, and is now almost streamless and may possibly be a glacial overflow channel. It is at a height of 1,157 feet above the sea.

After a light lunch at Glyn the quarries at Cae Deicws were visited.

These are excavated in a pale buff-coloured felsite containing porphyritic crystals of quartz and felspar.

The columns into which this rock has broken, as the result of contraction due to cooling, have assumed an exceedingly unusual form, being strongly curved. The rock is known locally as "China-stone."

The Cae Deicws Quarries are near the summit of a steep slope overlooking the Glyn Valley, and at the foot of the hill is another excavation in a somewhat similar rock. Here the junction of the igneous with the surrounding sedimentary rocks (Bala Slates) can be seen. Near the line of junction many fragments of limestone from the Bala Beds are included in the igneous rock. These fragments are little altered and are associated with numerous angular pieces of the felsite. It would appear that the marginal matter is of an ashy nature, and it was suggested on the ground that the felsite which occupies the centre of the quarry was a dyke intrusive in the ash beds.

Mr. Lomas, however, describes the section thus:—"The line of junction has evidently formed a plane of movement, for the marginal portions are sheared and contain fragments of slate, China-stone, and limestone."*

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* Proc. Geologists' Assn., Vol. XX., Pt. 7, p. 494.

After a walk of about 1½ miles along the railway Hendre Quarry at Pen-y-Bont was reached.

Near their line of junction with the Igneous rock, which is much more basic than that at Cae Deicws, the slates of the Bala Series are considerably altered, as is shown by the occurrence of Spotted-slate and Chiastolite-slate, both of which are produced as the result of the action of heat upon ordinary Clay-slate. The Igneous rock, which is basic and holocrystalline, is probably a Keratophyre, containing much augite and an acid felspar, and is used for setts and road metal.

From Hendre Bridge the party returned to Glyn Ceiriog and drove thence by Castle Mill, where several exposures in the Carboniferous Limestone were examined, to the large quarry at Bron-y-Garth on the right bank of the river.

The sections at Castle Mill were found to be in the same beds (D_2) as those examined earlier in the day, and the same was the case at Bron-y-Garth, where 100 feet of strata were exposed, consisting for the most part of limestone, but with a bed of shale some 20 feet in thickness near the top.

The following fossils were obtained :—

Lonsdalia duplicata.
Lithostrotion junceum.
L. irregulare.
L. McCoyanum.
Diphyphyllum.
Cyathophyllum regium.
Cyclophyllum pachyendothecum.
Productus latissima.
Phillipsia sp.

These rocks were stated to rest directly upon Bala Beds, which would place the local base of the Carboniferous exceptionally high in the series. No section showing the actual base of the series could, however, be found.

A General Meeting of the Society was held in the evening at the Wynnstay Hotel, under the presidency of Dr. Dwerryhouse, a number of members of the Liverpool Geological Society being present.

The Chairman referred to the great loss which had been sustained by geological science by the death of Dr. Henry Clifton Sorby, and referred to the pioneer work done by him in many branches of science.

Two new members were elected.

Mr. Joseph Lomas, A.R.C.Sc., F.G.S., then gave an address on the structure of the Berwyn District.

He described the Berwyns as a great dome some 300 square miles in area, and consisting for the most part of rocks of Bala age, with numerous Igneous rocks, both contemporaneous and intrusive.

The dome was described as the result of successive folding movements along lines parallel to the Caledonian axis, north-east to south-west, and the Pennine axis, north to south.

To the north-west of the dome and separated from it by the Bala Fault, lies a great syncline occupied by Silurian rocks.

This fault, where it crosses some of the anticlines, has been stated to have a throw of 13,000 feet, but where it enters the synclinal areas this dwindles to 4,000 feet.

The fault is pre-Triassic, and corresponds in direction and alignment with the Anglesark anticline, and it can be shown, in common with many of the larger dislocations in Britain, to have moved during several geological periods.

In this instance a pre-Carboniferous and also a post-Carboniferous movement can be demonstrated.

In dealing with the igneous rocks of the district, Mr. Lomas stated that some of them appeared to be of contemporaneous, while others were certainly intrusive.

As the succeeding paper was to deal with the Carboniferous rocks, Mr. Lomas did not treat of them in any detail.

In the discussion, Dr. Dwerryhouse pointed out that in at least one instance, viz., that near Glyn which was visited that day, there was a case of contemporaneous volcanic activity. This could be seen from the occurrence of a bed of ash with fragments of Bala Limestone and of a neighbouring Felsite.

The discussion then turned to the question of how far torsion structure had entered into the tectonics of the district, and this led to some discussion of torsion structure in general, but this had to be relegated to an informal conversation after the meeting.

The Chairman then called upon Dr. Wheelton Hind to give an address on the Carboniferous Rocks of North Wales.

Dr. Hind first referred to the pioneer work done by Mr. G. H. Morton, pointing out that this had been carried out entirely on lithological lines, and that although in the main the results were in accord with those obtained by the more modern palæontological methods, there was nevertheless considerable difference as regards details, the palæontological breaks sometimes occurring in the middle of one of Morton's lithological zones.

He then dealt with the nature of the floor underlying the Carboniferous Series, and was of opinion that there was a ridge of land separating North and South Wales, and that the northern part was not submerged until a much later period than the south.

The zoning of the rocks was then treated of in considerable detail.

In the discussion, Dr. Vaughan pointed out the great importance of the bathymetric level at which the different deposits were formed, and the necessity of giving full consideration to this in any attempt at zoning an alternating series of deep and shallow water deposits. The shore fauna of any period being invariably different from the oceanic fauna, it follows that the assemblage of fossils will also vary as between deep and shallow water deposits. It therefore becomes necessary to set up two zonal scales—one for shallow, and the other for the deeper deposits.

This does not necessarily affect the zoning of a mixed series of shales and limestones, as these may in reality belong to the same bathymetric level, the distribution of shales being controlled by varying currents.

Mr. Cosmo Johns pointed out that the base of the Millstone Grit rests on beds of various ages in different parts of the country. With regard to the irregularity of the sub-Carboniferous floor, he stated that he had seen bedding lines in the lower part of the Carboniferous Limestone Series which passed up against hills on the underlying floor.

On April 18th the members left Oswestry at 8.30 by train for Llangollen, the order of the programme having been altered to suit the convenience of several members who had to leave the district before the conclusion of the excursions.

A sharp walk of about two miles brought the party to the foot of the Carboniferous escarpment at Eglwyseg Rocks, where the Red Basement beds were examined and the escarpment then climbed, fossils being collected from the various beds exposed on the slope.

The lower portion of the limestone contains numerous large brachiopods—*Davisiella Llangollensis*—and it was concluded that the lower part of the series belonged to the Seminula zone.

Higher up the cliff, beds containing a lower Dibunophyllum fauna were encountered, and the party then went along the top of the escarpment to the extensive limestone quarries above Dinas Bran, where beds of D_1 age were found at the north-western end.

Passing along to the south-east, newer beds were encountered until the top of the limestone was reached in Bron Heulog Quarry. These beds are still in D_1.

From Bron Heulog eastwards the beds acquired a steeper easterly dip and the Cefn-y-Fedw Series was passed over, the beds occurring in the following order :—Pebbly Grits, Chert beds, and Yellow Sandstones. The return journey was by way of Trevor Station.

On April 19th some of the members drove from Oswestry to the racecourse, passing over Coal Measures, Cefn-y-Fedw Series, and Carboniferous Limestone. The cherts were examined at Underhill Farm and a few brachiopods were collected.

The famous gravel pits at Gloppa were then visited. These are excavated in morainic gravels, and the following erratics were observed :—

Nature of Specimen.	*Source.*
Granite	Criffel, Dumfriesshire.
Do.	Dalbeattie, Dumfriesshire.
Do.	Cairnsmore (?).
Do.	Eskdale, Cumberland.

Nature of Specimen.	*Source.*
Granophyre	Buttermere, Cumberland.
Andesitic Lava	Lake District.
Do. Ash	Do.
Felsite	North Wales.
Flint	Antrim.
Do. (red, burnt)	Do.
Silurian Grit	Southern Uplands.
Jasper	Do.
Red Sandstone (Penrith type)	(?)
Carboniferous Rocks	Local.
Turritella communis	Irish Sea.
Fusus sp.	
Cardium edule	
Cyprina Islandica	
Pecten sp.	

The shells were, for the most part, fragmentary and in many instances showed glacial striations.

The sandstones immediately above the Carboniferous Limestone were next examined in Allinson's Quarry. The rock is of a bright yellow colour and was found to contain *Cyathaxonia*, caninoid *Campophyllum*, and a few brachiopods. It was concluded that these beds belonged to the zone D_3.

Offa's Dyke was then crossed on the way to Llawnt, where further exposures of the Carboniferous beds were examined.

In Llawnt Quarry the beds of Carboniferous Limestone are considerably bent and contain two layers of shale, the dip on one side of the exposure amounting to 40° towards the east.

Although very near to the base of the series these beds are high in the zone D_2, the following fossils occurring :—

Dibunophyllum Muirheadi.
Lonsdalia duplicata.
Lithostrotion irregulare.
Syringopora sp.
Spirifera bisulcata.

In the road below the quarry the Bala shales are exposed, their dip and strike both differing considerably from those of the overlying Carboniferous, indicating a considerable unconformity. The actual junction cannot be seen.

In the upper quarry at Llawnt similar D_2 beds are exposed, and a curiously curved bed of shale proved, on examination, to be due to thrusting, which has taken place to a considerable extent along the bedding-planes, and which, it was suggested, might account for the absence of the lower part of the D_2 beds.

From Llawnt the party drove to Llansilin and Glas Coed, where several sections in Felsite and Bala shales were seen. One of the Felsite sections showed very well marked horizontal columns. The Carboniferous Series was seen to rest unconformably on these older beds, and the members then proceeded by way of Trefonen to Treflack Wood Quarries, in the Upper Grey Limestone of Moreton, which was found to belong to D_2, to Oswestry.

On April 20th the excursion was to the Llanrhaiddr and Cader Berwyn district.

A long drive in a somewhat keen air brought the party to Llanrhaiddr, whence they proceeded to the picturesque waterfall of Pystyll Rhaiddr.

The crest of the fall is formed by a bed of columnar Felsite, this being much harder than the overlying and underlying slates.

The shoulder of Cader Berwyn was then crossed, some of the hardier members ascending to the summit in spite of the bitter wind and occasional driving showers of snow and sleet, and a return was then made to Llanrhaiddr by a more circuitous route, a few trilobites being obtained from the Ordovician rocks on the way.

From Llanrhaiddr the members drove back to Oswestry.

The Summer Meeting was held at Richmond, from June 19th to June 22nd, under the presidency of Mr. J. J. Burton and leadership of Mr. William Horne, F.G.S., the headquarters being at the Fleece Hotel.

The route for Friday's excursion was through Skeeby over Watling Street, the old Roman highway, past the interesting Scotch Corner, where the east and west roads to Scotland diverge. Sedbury Duckett, with its reminiscences of the Moss troopers and their periodical raids, was noticed, and then Barton Quarry was reached. Interest here was divided between the limestone beds of the quarry and the remarkably fine exposures of the Boulder Clay which was being removed in order to enable the quarrying operations to be extended.

The limestone itself was simply one mass of broken stems of encrinites, which must have flourished abundantly in the carboniferous sea of this area.

In places the entire quarry face could be seen to be formed by the interlaced stems beautifully weathered out. There was just a question as to whether it was the Underset or Main limestone, but the evidence, such as it was, rather strengthened the view—commonly held—that it is the Underset. This is just one of the points where, in the present state of knowledge, the fossil evidence is not sufficient to enable the distinction to be made.

The chief point of interest, perhaps, was the beautifully polished and scratched upper surface of the limestone from which the Boulder Clay was being removed. The management had thoughtfully washed one portion where the groovings were very distinct. Nothing clearer in the way of evidence as to the direction of movement of the great glacier could be wished. It might, too, have caused the suggested diversion of the Tees, but while the members were quite willing to accept the glacier and its movements, the river diversion theory was held over for consideration until the leaders of the excursion had an opportunity of bringing forward more convincing evidence, than had been seen during the morning. After enjoying the hospitality of the proprietors of the quarry, the members drove through Aldbrough, with its spacious village green and interesting old houses.

A halt was called at the Forcett Quarry where lunch had been provided by the proprietors. Under the guidance of Mr. Abbott, the manager, the drift covering of the quarry and the uncovered pre-glacial floor with its clints and potholes were inspected. This old pre-glacial floor must have rather resembled the well-known surface of the Great Scar Limestone of Ingleborough. In the face of the quarry could be seen the ancient potholes that had been filled with drift when the glaciers of the Ice Age moved slowly over the land and obliterated many of its ancient features.

During the drive back to Richmond a halt was made near Kirby Hill, at the point which was indicated as being the watershed of the Tees and Swale. It was certainly very low, and looking over the Gilling Valley it did seem as if it were too broad to have been produced by the stream that now runs through it. The possibility that this might be a true explanation of the facts was admitted, but the generally expressed opinion was that though this was a possible case of river diversion, yet that it would be safer to wait for further facts before arriving at a final conclusion.

On Saturday morning the members walked to the Corporation Quarry, near the barracks at Richmond, where a Grey Limestone is exposed. This forms a part of the so-called " Red Beds." From the hill above the quarry a fine view over Richmond, with its fine Norman castle, and also of the distant hills, flanking the Swale Valley, was obtained.

A quarry near the racecourse was then visited, where a bed of chert occurs in the limestone and the limestone itself contains much gritty matter.

The walk was then resumed by way of Willance's Leap and thence down the hill to a British encampment in a wood at the foot of the cliff.

Near the monument many fossils were collected, including fish teeth.

These teeth belong to the cartilaginous group of fishes, which accounts for the fact that no remains other than the teeth and a few dorsal spines are preserved.

The view looking up Swaledale from Willance's Monument is one of the finest in the dale. Throughout this section of its course the river is still cutting in glacial drift, having as yet failed to clear its valley of the accumulation of loose materials produced during the Glacial Period.

The Swale Bridge was then crossed, and the return journey was by the right bank of the river. Several quarries in the Main Limestone and Red Beds were examined *en route*, and an interesting dry valley of great depth and probably of glacial origin, lying behind Round How, was traversed. Opposite Round How the present valley of the Swale is much obstructed by glacial drift, and it may be that in this fact lies the explanation of the dry valley.

The copper mine on the right bank of the Swale, opposite Richmond, was then visited, and specimens of Malachite, Azurite, and Copper pyrites were seen.

The evening meeting was held at the Fleece Hotel, under the presidency of Mr. J. J. Burton. Two new members were elected.

Mr. Robinson (Sedbergh) proposed a vote of thanks to the President and to Mr. Horne for his able leadership of the field excursions, also to the owners of property for the facilities which they had granted.

Mr. Cosmo Johns opened a discussion on the position of the boundary between the Lower and Upper Carboniferous. He described the early work of Phillips, who drew his line at the top of the Main Limestone.

Above these are the Black and Red beds of Wensleydale, which Phillips placed in the Millstone Grit (Upper Carboniferous).

Dr. Dwerryhouse pointed out that the Millstone Grits of the South of England were very different from those of Lancashire and Yorkshire, and may well have had a separate origin. Hence the base of the Millstone Grit, viewed as a lithological division, may be at different horizons in different parts of the country.

Mr. William Simpson suggested that the marine fauna of a series must naturally develop further and show higher forms in the portion of the area which was last to shoal than in the peripheral portion which shoaled earlier.

On the 21st a few of the members revisited the section near Willance's Leap with the object of working out the beds above the Main Limestone.

The chert beds in the upper part of Deepdale were found to be highly fossiliferous, and a large number of specimens was collected for future investigation. Throughout the excursion the weather was excellent.

The Autumn Meeting of the Society was held from September 25th to 28th at Saltburn, the headquarters being at the Queen Hotel.

Mr. W. Y. Veitch, F.G.S., was the president of the meeting, and the leaders of the excursions were Professor Kendall, M.Sc., F.G.S., and Mr. J. W. Stather, F.G.S.

The object of the meeting was two-fold ; in the first place, to investigate the plant-bearing beds of the Lower Oolite Series in the neighbourhood of Marske, and secondly, to study the relations of the Dogger to the overlying and underlying formations.

The quarry at Marske has long been famous for its fossil plants, but has recently acquired particular interest owing to the work of Wieland and others on the evolution of the Cycads and other closely related plants.

As the remains of these plants occur in considerable numbers and in an exceptionally good state of preservation in the Saltburn district, it was hoped that some new light might be thrown on the question during the visit.

The members to the number of about 12 left Saltburn at 9 o'clock to walk to Marske, where they were joined by others who had journeyed by train. After a walk of two miles the disused sandstone workings at Marske Quarries were reached. Here, by the kind permission of Mr. Senior, agent to the Marquis of Zetland, several shots were fired so as to reopen the section, which had become considerably overgrown by bracken and covered by talus. A number of fossil plants was collected, some of them being in a very fine state of preservation.

The quarries are in the Lower Oolite which forms the top of the hill, from which a fine view was obtained of the plane which fringes the coast and on which Redcar, Marske, and Saltburn are built.

On the lower slopes of the hill are extensive workings in the main seam ironstone of the Middle Lias.

A question arose as to the nature of the beds lying between these Middle Lias deposits, and the Lower Oolites on the crest of the hill. The space available being insufficient for the normal thickness of the Upper Lias, this must either be missing from the section or much reduced in thickness.

On Saturday, 26th September, a party left Saltburn at 7.15 a.m. for Whitby, for the purpose of investigating the cliff sections in the neighbourhood of Saltwick Nab.

After breakfast at Whitby, the members walked along the foot of the cliffs by the harbour and examined the alum shales of the Upper Lias.

Proceeding along the Scars in the direction of Saltwick the Dogger was next examined, with a view to ascertaining the conditions under which it was deposited.

The Dogger contains fragments of ammonites derived from the underlying Liassic beds. Some difference of opinion has arisen as to the exact portion of the Lias from which these fossils have been derived, and a number was collected with a view to their subsequent identification and the possible clearing up of the matter.

At the top of the Alum Shales a number of fossil roots was found; these appeared to be connected with a vertical trunk which penetrated the overlying Dogger. It is intended to make a small excavation for the purpose of demonstrating whether or no the roots are actually connected with the trunk, as several matters of considerable interest would be raised if this were found to be the case.

Some months ago Mr. Harold Brodrick, a member of the Society, found some reptilian footprints on a fallen block of sandstone in the Saltwick Alum Quarries, but was unable to determine the exact horizon from which the block had fallen. Those attending this excursion were more fortunate, several similar footprints being found on recently fallen blocks midway between the East Pier at Whitby and Saltwick Nab. The fall had left a fresh scar on the cliff face, and by this means it was possible to determine the position of the footprint bed. The bed is, however, in an inaccessible position near the summit of the cliff, so that it was impossible to observe the impressions *in situ*.*

The largest impression observed was about 12 inches in length, which would point to the creature which made it being at least 12 feet in height. The footprints were those of the hind feet only and were associated in one instance with sun-cracks and rain pittings, and in another with ripple-marked surfaces. The sandstone in which the various impressions occur is strongly current-bedded and was therefore probably deposited in shallow water. Some of the layers also contained fossil coniferous plants.

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* The actual bed with footprints *in situ* and associated with the fresh-water lamellibranch *Unio* has since been found by Prof. Kendall and a party of undergraduates of the University of Leeds.

The sandstone belongs to the Lower Estuarine Series which immediately overlies the Dogger, the footprint bed being about 70 feet above that formation.

The members returned to Saltburn by train in time for the General Meeting, which was held in the evening at the Queen Hotel.

In the unavoidable absence of Mr. W. Y. Veitch, the chair was taken by Mr. J. W. Stather, F.G.S.

The following gentlemen were unanimously elected members of the Society :—

Mr. Frank Elgee, Middlesbrough ;
Mr. Foster, Doncaster ; and
Mr. E. H. Chapman, London and Whitby.

Mr. Elgee read a paper on " The Glaciation of North Cleveland," in which he dealt with certain valleys produced by the overflow of glacial lakes during the retreat of the ice. The paper was followed by a discussion (see pp. 372-382).

The Chairman then called upon Dr. Dwerryhouse to give a brief *résumé* of the work done during the excursion.

Mr. Simpson proposed and Mr. Bingley seconded a vote of thanks to the owners of property traversed during the excursions for the facilities which they had granted, to the leaders of the excursions, and to Mr. Elgee for his interesting paper.

On the 27th some of the members walked along the beach by the foot of Hunt Cliff to examine the Middle Lias, and proceeded to the Skinningrove Iron Works, where, by kind permission of Mr. Hutchinson, they were conducted over the premises. Here specimens of the various ores in use were examined, and the members returned by the cliff top to Saltburn, examining some exposures of the main seam ironstone *en route*.

On Monday morning an excursion was made along the North Beach at Saltburn for the purpose of examining the cliffs of Boulder Clay between Saltburn and Marske.

THE YORKSHIRE GEOLOGICAL SOCIETY.

Statement of Receipts and Expenditure, October 31st, 1907, to October 31st, 1908.

REVENUE ACCOUNT.

Dr.

1907.	**Receipts.**	£	s.	d.
Nov. 1	To Balance in Bank	15	11	5
1908.				
Oct. 31	,, Life Member's Subscription transferred from Capital A/c	6	6	0
	,, Members' Annual Subscriptions	76	14	0
	,, ,, ,, ,, (arrears paid)	5	4	0
	,, Sale of Proceedings	1	2	6
	,, Authors' Reprints	4	10	2
	,, Halifax Corporation, Interest on Mortgage Bonds	11	17	9
		£121	5	10

Cr.

1908.	**Expenditure.**	£	s.	d.
Nov. 1	By Cost of Proceedings (Chorley & Pickersgill, Ltd.), including Reprints and Postages ...	59	4	1
	,, Sundry Printing, Stationery, Circulars, &c.	22	4	10
	,, Meetings and Excursions	4	17	3
	,, Hon. Secretary's Postages and Petty Cash...	1	2	7
	,, ,, Treasurer's ,, ,, ...	1	5	5½
	,, ,, Editor's ,, ,, ...	0	17	0½
	,, Maps and Books (Rev. W. L. Carter) ...	0	12	6
	,, Legal Agreement and Cost of Removing Library	1	16	11
	,, Cheque Book	0	2	6
	,, Balance in Bank	29	2	8
		£121	5	10

CAPITAL ACCOUNT.

1908.		£	s.	d.
Oct. 31	To Halifax Corporation Mortgage Bonds ...	360	0	0
	,, One Life Member's Subscription	6	6	0
	,, Books, Proceedings, Maps, &c., at the Leeds University, as per Agreement dated 20th November, 1907, in the custody of the Halifax Joint Stock Banking Co. ...			
		£366	6	0

1908.		£	s.	d.
Oct. 31	By Transfer to Revenue A/c	6	6	0
	,, Halifax Corporation Mortgage Bonds ...	360	0	0
		£366	6	0

Leeds, November 1st, 1908.

Examined and found correct,
F. W. BRANSON, *Hon. Auditor.*

WILLIAM SIMPSON,
Hon. Treasurer.

OFFICIAL LIST OF MEMBERS.

HONORARY MEMBERS.

1887 Bodington, N., Litt.D., Vice-Chancellor, The University, Leeds.

1887 Hughes, Prof. T. McK., M.A., F.R.S., F.G.S., Ravensworth, Brooklands Avenue, Cambridge.

1887 Judd, Prof. Jno. W., C.B., LL.D., F.R.S., F.G.S., 30, Cumberland Road, Kew, Surrey.

1887 Woodward, Henry, LL.D., F.R.S., 13, Arundel Gardens, Notting Hill, London, W.

1907 Woodward, Arthur Smith, LL.D., F.R.S., F.L.S.

1898 Whitaker, William, B.A., F.R.S., F.G.S., Freda, Campden Road, Croydon.

ORDINARY MEMBERS.

* Life Members who have compounded for the annual subscriptions.

Elected.

1883*Abbott, R. T. G., F.S.I., Whitley House, Malton.

1907*Ackroyd, Hy. Ed. P., Dean House, North Brierley, Bradford.

1903 Ackroyd, Wm., M.E., F.I.I., Nan Tan, Wortley, Leeds.

1901*Anderson, Tempest, M.D., F.G.S., 17, Stonegate, York.

1899 Appleyard, J. H. R., B.Sc., 5, Willow Lane East, Huddersfield.

1908 Archer, J. Fletcher, B.A., M.I.Mech.E., 48, High Street, Doncaster.

1900 Ashley, Theodore, Mustia Colliery, Asansol E.I.R., Bengal, India.

1900 Ashworth, John Hoyle, Wood Rhydding, Ilkley.

1875 Atkinson, J. T., F.G.S., Solicitor, Selby.

1879*Bartholomew, C. W., Blakesley Hall, near Towcester.

1878 Bedford, J. E., F.G.S., Arncliffe, Shire Oak Road, Headingley, Leeds.

1903 Beverley, Robert B., Heath House, Wakefield.

1895 Bingley, Godfrey, Thorniehurst, Shaw Lane, Headingley, Leeds.

1905 Booth, John, 15, School Hill, Windhill, Shipley.

1907 Booth, Peter, 65, Richmond Avenue, Leeds.

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OF THE
Yorkshire Geological Society.

NEW SERIES, VOL. XVI., PART I., PAGES 1—136, AND
LIST OF MEMBERS.

With Fourteen Plates.

Edited by W. LOWER CARTER, M.A., F.G.S., and
ARTHUR R. DWERRYHOUSE, D.Sc., F.G.S.

1906.

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This Society was founded in the year 1837 at a meeting of coal proprietors of the West Riding at Wakefield, and for nearly forty years its operations were confined to that Riding. The purposes for which it was formed were the investigation of the Yorkshire Coalfield and the gathering of such definite information about its seams of coal and ironstone as would be of use in the prosecution of mining operations. The scope of the Society was soon enlarged to include the Arts of Mining and Metallurgy and their dependent manufactures, and of the machinery and tools employed therein, and the name was correspondingly expanded to "Geological and Polytechnic." The subscription was originally half-a-guinea, but when Proceedings were published half-a-crown extra was added to meet the cost. In 1838 the work of establishing a Museum was commenced, and in 1839 the preparation of section across the Pennine Chain was commenced. Meetings were held regularly at which papers on geology, palaeontology, mining, and kindred topics were read and discussed. In 1877 the rules were revised and it was decided to extend the Society's operations from the West Riding to the whole county. In addition to the ordinary meetings of the Society, from time to time investigations were undertaken by the aid of funds specially raised. Among these were the investigation of the bone-bearing deposits of Raygill, the pre-historic mounds of Grassington, the source of the Aire at Malham, and the Underground Waters of Ingleborough. In the two latter the Society worked in conjunction with a Committee of the British Association. At the Annual Meeting in 1906 it was resolved to change the title to "The Yorkshire Geological Society."

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OF THE

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New Series, Vol. XVI., Part II., Pages 137—245, and
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1907.

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Yorkshire Geological Society.

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